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SYSTEM OPTIMIZATION OF GASDYNAMIC LASERS

COMPUTER PROGRAM USER'S MANUAL

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SUMMARY

This report contains the user's manual for the computer program described in reference 1. Gasdynamic laser systems or subsystems can be optimized by using this manual in conjunction with reference 1. This manual assumes familiarity with gasdynamic laser systems and with large-scale computer models.

PROGRAM DESCRIPTION

Necessarily, the computer code that performs this analysis is large and complex. In its present form, it has 32 subroutines and in excess of 6600 FORTRAN statements, of which perhaps 10-20% are comments. The code is written in a dialect of FORTRAN and was originally intended for the Control Data Corporation 6600/7600 computers. Hence, it uses a few language features and programming techniques that are unique to that machine. It has recently been converted to other machines, however, including the International Business Machines 360/370 computers, so its machine-dependence is minimal. A single analysis pass requires from 3 to 5 sec on the CDC 7600, and a typical optimization may require 300 sec or more. The program requires $106{,}000_8$ words of memory on the CDC 7600 and operates without overlay or segments on this system. No external storage such as magnetic tape is required.

The program consists of five modules, as shown in figure 1. The control module performs certain input and output functions, maintains the flow of information between modules, and calls the other modules at the appropriate time. The optimization module (CONMIN) is used to minimize or maximize some features of the system. The remaining three modules (GAIN, FLAME, and WTVOL) are the physical models and calculate the laser performance, combustion information, and weight/volume results, respectively. The modules and the FORTRAN subroutines associated with each of them are summarized in table 1.

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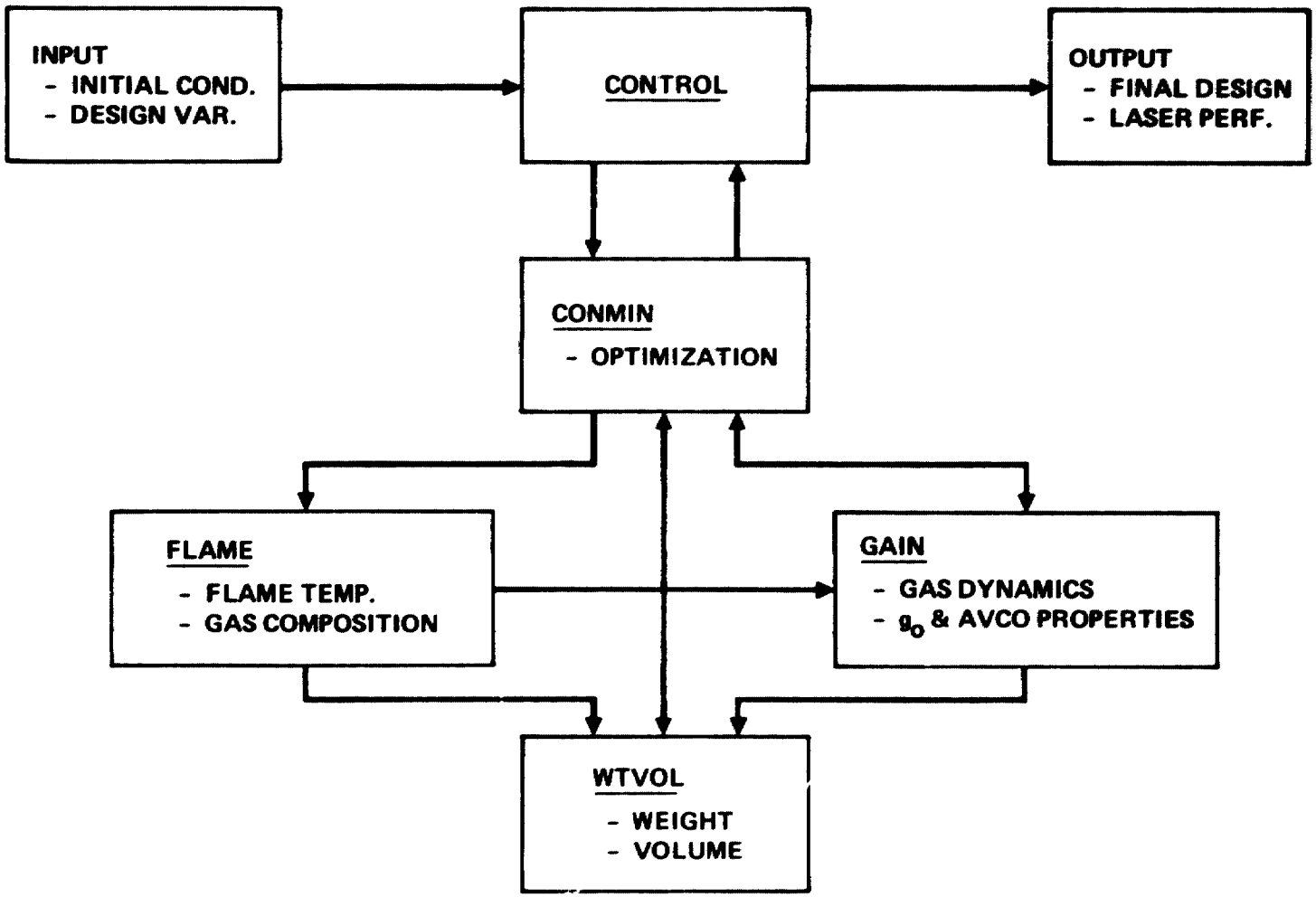

Figure 1.- Program structure.

TABLE 1.- PROGRAM MODULES AND SUBROUTINES

Module	Function	Associated subroutines
CONTROL	I/O control; communication	COPES2* COPEØ1 COPEØ2 COPEØ3 COPEØ4 COPEØ5 COPEØ6 COPEØ7
CONMIN	Optimization	CONMIN* CNMNØ1 CNMNØ2 CNMNØ3 CNMNØ4 CNMNØ5 CNMNØ6 CNMNØ7 CNMNØ8
GAIN	Laser gasdynamics and kinetics; gain, available energy	CYCLE* CHAR DERFC FLUX TAUSUB RUNGEX EV NOZZLE CONTOUR MACH GAMMA TABNOZ AVG
FLAME	Combustion products; flame temperature	FLAME*
WTVOL	Weight; volume	WTVOL*

*Denotes entry point.

Because this program was developed over an extended period of time, each of the physical model modules (GAIN, FLAME, and WTVOL) was initially written to run on its own. Therefore, each of these modules was required to read the information it needed, execute, and write the output on its own. For simplicity, this structure was retained in the integrated program. In addition to making module development easier, the use of this structure permits easy substitution of any of the modules. Execution sequence is controlled by the CONTROL module.

Communication between the modules and especially with the control module is handled by a single labeled COMMON block, GLOBCM. A parameter's position in this block is used to identify its role in the sensitivity analysis or optimization process. The contents of this block, called the global COMMON block, are shown in table 2. In the version described here, only the first 35 elements of this block are used; the remaining 1465 are available for future use or can be deleted if memory space is at a premium.

TABLE 2.- GLOBAL CATALOG

Location	FORTRAN name	Definition	Units	Defined by[a]	Used by[a]
1	TSTAG	Combustor stagnation temperature	K	1, 2	1, 3
2	PSTAG	Combustor stagnation pressure	atm	1	1, 3
3	THROAT	Cavity nozzle throat height	mm	1	1, 3
4	AEXIT	Cavity nozzle area ratio	---	1	1
5	XC	Mole fraction of CO_2	---	1, 2	1
6	XH2	Mole fraction of H_2O	---	1, 2	1
7	XCO	Mole fraction of CO	---	1	1
8	XHE	Mole fraction of H_e	---	1	1
9	ELSUB	Length of subsonic portion of nozzle	cm	1	1
10	ELNOZ	Length of supersonic portion of nozzle	cm cm	1 1	1
11	C	Length of 1st section of nozzle	cm	1	1
12	RAD	Length of 2nd section of nozzle	cm	1	1
13	THETA1	1st nozzle angle	deg	1	1
14	THETA2	2nd nozzle angle	deg	1	1
15	BIG	Maximum peak gain	%/cm	1	1
16	PAVG	Average available specific energy	kJ/lb	1	1, 3
17	CHI	Ratio of moles of carbon to moles of C-N-O-H fuel	---	2	2

[a] 1 - GAIN
2 - FLAME
3 - WTVOL

TABLE 2.- Concluded

Location	FORTRAN name	Definition	Units	Defined by[a]	Used by[a]
18	Q	Moles of excess oxidizer	---	2	2
19	R	Ratio of moles of N_2 to moles of C-H-O-H fuel (OX/AIR)	---	2	2
20	S	Ratio of moles of excess CO_2 to moles of C-N-O-H fuel	---	2	2
21	DELNX	Additional oxidizer temp. due to preheat	K	2	2
22	DELN2	Additional makeup N_2 temp. due to preheat	K	2	2
23	QFRAC	Mole fraction of N_2 that is preheated	---	2	2
24	WTO	System weight (old bench)	lb	3	3
25	VT	System volume (old bench)	ft^3	3	3
26	WTO2	System weight (new bench)	lb	3	3
27	VT2	System volume (new bench)	ft^3	3	3
28	B	Cavity/mirror height	in.	3	1, 3
29	ARCAV	Cavity aspect ratio	---	3	3
30	P	Static pressure at end of cavity	atm	1	3
31	EM	Mach number at end of cavity	---	1	3
32	PGAM	Cavity process γ	---	1	3
33	ETA	Diffuser efficiency (times normal shock)	---	3	3
34	PØ-PØMIN	Actual minus required pressure at end of diffuser (>Ø for recovery)	psi	3	3
35	ETAN2	Ratio of moles of N_2 to moles of N_2 in air (OX/AIR)	---	2	2

PROGRAM USAGE

The program input is divided into five sections. The first section is CONTROL and CONMIN input. The second section selects which options among the physical models will be used. The remaining sections are the inputs for the physical model modules. The first two sections of input are mandatory for any problem. The remaining sections of input depend on the particular problem under investigation.

This section provides a card-by-card description of the input and presents a sample. The format for each card is given in parenthesis after the contents, and a description of the contents is given below it.

A. CONTROL and CONMIN Input (Mandatory)

Card 1: TITLE (20A4)

TITLE - any alphanumeric title, up to 80 characters.

Card 2: NCALC, NDV, NSV, N2VAR, IPNPUT, IPSENS, IP2VAR (715)

NCALC - calculation control.

- 0: read input and stop. All other control input is optional.
- 1: cycle through program once. All other control input is optional.
- 2: do optimization. Additional control input of Cards 3-10 is required. All other control input is optional.
- 3: do sensitivity analysis. Additional control input of Cards 11-14 is required. All other control input is optional.
- 4: do optimum sensitivity. Additional control input of Cards 3-14 is required. All other control input is optional.
- 5: do two-variable analysis (all combinations of two variables). Additional control input of Cards 15-18 is required. All other control input is optional.
- 6: do optimum two-variable analysis. Additional control input of Cards 3-10 and 15-18 is required. All other control input is optional.

NDV - number of design variables in optimization or optimum sensitivity.

NSV - number of sensitivity variables.

N2VAR - number of objective functions in a two-variable analysis.

IPNPUT - input print control.

- 0: print card images plus formatted print.
- 1: formatted print only.
- 2: no print of input.

IPSENS - sensitivity print control.

0: no detailed print each sensitivity analysis.

1: detailed print each sensitivity analysis.

(DEFAULT: 0)

IP2VAR - two-variable analysis print control.

0: no detailed print each two-variable analysis.

1: detailed print each two-variable analysis.

(DEFAULT: 0)

- - - - - - - - - - - - - - - - - - OPTIMIZATION - - - - - - - - - - - - - - - - -

Card 3: IPRINT, ITMAX, ICNDIR, NSCAL, ITRM, LINOBJ, NACMX1, NFDG (815)

IPRINT - optimization print control.

0: no print.

1: print initial and final optimization information.

2: 1 plus function value and design variable values at each iteration.

3: 2 plus constraint values, direction vector, and move parameter at each iteration.

4: 3 plus gradient information.

ITMAX - maximum number of optimization iterations (DEFAULT = 10)

ICNDIR - conjugate direction restart parameter (DEFAULT = 3)

NSCAL - scaling frequency. Design variables are scaled every NSCAL iteration. (DEFAULT = 0, no scaling)

ITRM - number of successive iterations which must satisfy convergence criteria (see Card 5) before optimization is terminated.

(DEFAULT = 3)

LINOBJ - linear objective function identifier.

0: objective function is nonlinear function of design variables.

1: objective function is linear function of design variables.

(DEFAULT = 0)

NACMX1 - number of anticipated active constraints plus 1.

(DEFAULT: NDV + 2)

NFDG - finite difference gradient identifier.

0: gradients computed by finite difference.

1: gradient of objective computed analytically, gradients of constraints computed by finite difference.

2: all gradients computed analytically.

(DEFAULT = 0)

Card 4: FDCH, FDCHM, CT, CTMIN, CTL, CTLMIN, THETA, PHI (8F10.2)

FDCH - relative finite difference size for gradient calculation.

(DEFAULT - 0.01)

FDCHM - absolute finite difference size for gradient calculation.

(DEFAULT - 0.001)

CT - constraint thickness parameter.

(DEFAULT - 0.05)

CTMIN - minimum absolute value of CT

(DEFAULT - 0.004)

CTL - constraint thickness parameter for linear and side constraints.

(DEFAULT - 0.01)

CTLMIN - minimum absolute value of CTL.

THETA - mean value of push-off factor.

(DEFAULT - 1.0)

PHI - participation coefficient

(DEFAULT = 5.0)

Card 5: DELFUN, DABFUN (2F10.2)

DELFUN - minimum relative change in objective function. Used to terminate optimization.

(DEFAULT = 0.001)

DABFUN - minimum absolute change in objective function. Used to terminate optimization.

(DEFAULT = 0.001)

Card 6: NDVTOT, IOBJ, SGNOPT (2I5,F10.2)

NDVTOT - total number of variables linked to the design variables. NDVTOT must be greater than or equal to NDV (see Card 2). This option allows two or more parameters to be assigned to a single design variable. The value of each parameter is the value of the design variable times a multiplier, which may be different for each parameter.

(DEFAULT: NDV)

IOBJ - global catalog location of objective function for optimization.

SGNOPT - optimization control.

-1: minimize objective function.

+1: maximize objective function

Card 7: VLB(I), VUB(I), X(I) (3F10.2)

VLB(I) - lower bound on Ith design variable.

VUB(I) - upper bound on Ith design variable.

X(I) - initial value of Ith design variable (if ≠ 0, it overrides the value read later)

NOTE: NDV (see Card 2) of these cards are required.

Card 8: NDSGN(I), IDSGN(I), AMULT(I) (2I5,F10.2)

NDSGN(I) - number associated with the Ith design variable.

IDSGN(I) - global catalog location of Ith design variable.

AMULT(I) - constant multiplier on the Ith design variable.

NOTE: NDV (see Card 2) of these cards are required.

Card 9: NCONS (I5)

NCONS - number of constraint sets in an optimization.

Card 10: ICON(I), JCON(I), LCON(I), BLU(I,1), BLU(I,2), BLU(I,3) (3I5,3F10.2)

ICON(I) - first global catalog location of the Ith constraint variable.

JCON(I) - last global catalog location of the Ith constraint variable.

(DEFAULT = ICON(I))

LCON(I) - constraint identifier for the Ith constraint variable.

1: linear constraint

0: nonlinear constraint

BLU(I,1) - lower bound on Ith constraint variable.

BLU(I,2) - upper bound on Ith constraint variable.

BLU(I,3) - scaling factor on Ith constraint variable.

(DEFAULT = (BLU(I,1) + BLU(I,2))/2.)

NOTE: NCONS (see Card 9) of these cards are required.

- - - - - - - - - - - - - - - SENSITIVITY ANALYSIS - - - - - - - - - - - - - - -

Card 11: NSOBJ (I5)

NSOBJ - number of objective functions for sensitivity analysis

Card 12: NSENSZ(I), I = 1, NSOBJ (1615)

NSENSZ(I) - global catalog location of Ith sensitivity objective function.

Card 13: ISENS(I), NSENS(I) (2I5)

ISENS(I) - global catalog location of Ith sensitivity variable.

NSENS(I) - number of values of Ith sensitivity variable.

Card 14: SENS (I, J)

SENS (I, J) - values of Ith sensitivity variable (J = 1 is nominal value)

NOTE: NSV (see Card 2) of Cards 13-14 are required.

- - - - - - - - - - - - - TWO-VARIABLE FUNCTION SPACE - - - - - - - - - - - -

Card 15: N2VX, M2VX, N2VY, M2VY (4I5)

N2VX - global catalog location of X-variable.

M2VX - number of values of X-variable.

N2VY - global catalog location of Y-variable.

M2VY - number of values of Y-variable.

Card 16: N2VZ(I), I = 1, N2VAR (5I5)

N2VZ - global catalog location of Ith objective. N2VAR is defined by Card 2.

Card 17: XM2V(I), I = 1, M2VX (8F10.2)

XM2V(I) - Ith value of X-variable. M2VX is defined by Card 15.

Card 18: YM2V(I), I = 1, M2VY (8F10.2)

YM2V(I) - Ith value of Y-variable. M2VY is defined by Card 15.

Card 19: END

The word 'END' must appear here at the end of the control input.

B. OPTION Input (Mandatory)

A single card in NAMELIST format is used for inputting to this section.

Card 20: WEIGHT, BURNER, LASER, VLCAV, DEBUG (5L, NAMELIST "OPTION")

WEIGHT - is the WTVOL module to be used?

(DEFAULT = F)

BURNER - is the FLAME module to be used?

(DEFAULT = F)

LASER - is the GAIN module to be used?

(DEFAULT = T)

VLCAV - is the cavity calculation to be carried 2 mirror diameters downstream? If not, the input value on Card 29 will be used. It is valid only if WEIGHT = T.

(DEFAULT = F)

DEBUG - write debug output?

(DEFAULT = F)

NOTE: The WTVOL module cannot be run alone (i.e., BURNER = F, LASER = F, WEIGHT = T), since certain parameters normally supplied by GAIN would not be available. FLAME and GAIN may be run alone.

C. WTVOL Input

A single card in NAMELIST format is used for inputting this data. This card should be present only if WEIGHT = T (see Card 20).

Card 21: TP, TF, B, EMEXIT, PØEXIT, ETA, EFF, N, NOMISC, NOVALV (7F,1I,2L, NAMELIST "SIZE")

TP - power out of laser cavity, in watts.

(DEFAULT = 5×10^5)

TF - shot length, in seconds.

(DEFAULT = 2.0)

B - nozzle/mirror height, in inches.

(DEFAULT = 5.0)

EMEXIT - Mach number at the diffuser exit.

(DEFAULT = 0.9)

PØEXIT - total pressure at the diffuser exit, in PSI.

(DEFAULT = 14.7)

ETA - diffuser efficiency, in multiples of normal shock efficiency.

(DEFAULT = 0.5)

EFF - cavity extraction efficiency.

(DEFAULT = 1.0)

N - number of shots.

(DEFAULT = 15)

NOMISC - is "miscellaneous" weight to be omitted from the total system weight?

(DEFAULT = F)

NOVALV - is "valve" weight to be omitted from the total system weight?

(DEFAULT = F)

D. FLAME Input

A single card in NAMELIST format is used for inputting this data. This card should be present only if BURNER = T (see Card 20).

Card 22: CHI, Q, R, S, ETAN2, QFRAC, KFUEL, KOXID
(8F,2I, NAMELIST "PROPER")

CHI - moles of C to moles of C-N-O-H.

(DEFAULT = 0.0)

Q - moles of excess air (if air is oxidizer).

(DEFAULT = 0.0)

R - moles of N_2 to moles of C-N-O-H (if oxidizer is not air).

S - moles of excess CO_2 to moles of C-N-O-H.

(DEFAULT = 0.0)

ETAN2 - moles of N_2 to moles of N_2 in air (if oxidizer is air).

(DEFAULT = 1.0)

DELN2 - additional oxidizer temperature due to preheating, in degrees Kelvin.

(DEFAULT = 0.0)

DELN2 - additional makeup nitrogen temperature due to preheating, in degrees Kelvin.

(DEFAULT = 0.0)

QFRAC - fraction of makeup nitrogen at temperature DELN2.

(DEFAULT = 1.0)

KFUEL - fuel choice.

1: carbon monoxide (CO)

2: cyanogen (C_2N_2)

3: carbon and benzine ($C + C_6H_6$)

4: carbon (C)

5: benzonitrile (C_7H_5N)

KOXID - oxidizer choice.

1: oxygen (O_2)

2: nitrous oxide (N_2O)

3: nitrogen tetraoxide (N_2O_4)

4: air

E. GAIN Input

This input section retains the format from the original code and, hence, a number of superfluous or redundant cards is still necessary, chiefly for (now nonexistent) plotting. Likewise, some of the input described below is for features of the code that have little utility in many problems, notably the restart capability. This entire section should be omitted if LASER = F (see Card 20).

Card 23: LASTPLT (I1)

LASTPLT - an inactive plot parameter. It should be set to 1.

Card 24: IDO, TITLE (I1, 7A10)

IDO - an inactive plot parameter. It should be set to 2.

TITLE - any alphanumeric title, up to 70 characters.

Card 25: TITLE2

TITLE2 - any alphanumeric title, up to 80 characters.

Card 26: IPLOT (I1)

IPLOT - an inactive plot parameter. It should be set to 3.

Card 27: **ITEST** (I1)

ITEST - an inactive flag. It should be set to 0.

Card 28: **COMNT1** (8A10)

COMNT1 - any alphanumeric title up to 80 characters.

Card 29: **TSTAG, PSTAG, AEXIT, THROAT, XMAX, ANGLE, FACTOR** (7F10.0)

TSTAG - combustor stagnation temperature, in degrees Kelvin. If BURNER = T (see Card 20) this value is ignored.

PSTAG - combustor stagnation pressure, in atmospheres.

AEXIT - nozzle area ratio.

THROAT - nozzle throat height, in millimeters.

XMAX - maximum downstream distance over which cavity conditions are computed, in centimeters. If VLCAV = T and WEIGHT = T (see Card 20), this value is ignored.

ANGLE - cavity divergence angle, in degrees.

FACTOR - nozzle friction factor ($=1/2\ \rho u^2$)

Card 30: XC, XH2, XCO, XHE, JJ (4F10.0,I2)

XC - mole fraction of CO_2. If BURNER = T (see Card 20), this value is ignored.

XH2 - mole fraction of H_2O. If BURNER = T (see Card 20) and a water-producing fuel is used, XH2 is added to the resulting water fraction.

XCO - mole fraction of He.

JJ - rotational quantum number at which gain is computed.

NOTE: Gain is also calculated at the rotational quantum number at which it is greatest.

Card 31: ITAUSR, IRSTRT, IFLUX, ISUB, ITABLE, IRATE, IH2, JJ, IPRINT (9I1)

ITAUSR - water rate flag.

0: use nominal rate.

1: use Sharma rate.

IRSTRT - restart flag.

0: don't use restart option.

1: use restart option.

IFLUX - flux flag.

0: cavity flux is not present.

1: cavity flux is present.

ISUB - subsonic nozzle contour flag.

0: use stored values.

1: use external contour (see Cards 40-41)

2: use CONTOUR subroutine (see Card 42)

3: use previous values.

4: special nozzle 1.

5: special nozzle 2.

6: special nozzle 3.

7: use Mach number derivative subroutine.

ITABLE - supersonic nozzle contour flag.

0: use default contour (method-of-characteristics contour for a Laval nozzle)

1: use table look-up.

IRATE - vibrational probabilities flag.

1: use external values (see Cards 34-39).

0: use stored values.

IH2 - hydrogen rates flag.

1: don't use AFWL hydrogen rates.

2: use AFWL hydrogen rates.

IJ - inactive plot parameter. It should be set to 0.

IPRINT - print flag.

0: normal print.

1: additional print at every step from X = 0.05 cm to X = 0.5 cm in the cavity.

Card 32: DELX, ELSUB, ELNOZ, SLOPE, CURVE (5F10.0)

DELX - print interval for cavity calculations, in cm.

ELSUB - length of converging (subsonic) portion of the nozzle, in cm. $A/A^* = 10$ at X = ELSUB.

ELNOZ - length of diverging (supersonic) portion of the nozzle, in cm.

SLOPE - slope of the nozzle contour at X = 0. It is ignored if ELNOZ = 0.

CURVE - radius of curvature of the nozzle contour at X = 0.

Card 33: PHI, XBMON, XBMOFF (3F10.0)

PHI - cavity optical flux, in watts/cm^2.

XBMON - downstream distance where flux starts, in cm.

XBMOFF - downstream distance where flux stops, in cm.

NOTE: Include this card only if IFLUX ≠ 0 (see Card 31).

Card 34: B1, B2, B3, B4 (4F18.0)

Card 35: B5, B6, B7, B8 (4F18.0)

Card 37: B19 (F18.0)

B1-B19 - coefficients of probability functions describing vibrational relaxation processes. They are specified in the form $B_i F_i$ (T); where B_i are constants and F_i are specific polynomials contained in subroutine TAUSUB.

NOTE: Include these cards only if IRATE = 1 (see Card 31).

Card 38: TAU31, SIGC, SIGN, SIGN2 (4F18.0)

Card 39: SIGHE (F18.0)

TAU31 - transitional lifetime for the $CO_2(001) \rightarrow CO_2(100)$ transition, in seconds.

SIGC - optical broadening collision cross section for collisions between CO_2, in cm^2.

SIGN - optical broadening collision cross section for collisions between N_2, in cm^2.

SIGH2 - optical broadening collision cross section for collisions between H_2O, in cm^2.

SIGHE - optical broadening collision cross section for collisions between He, in cm^2.

NOTE: Include these cards only if IRATE = 1 (see Card 31).

Card 40: CM1, CM2, CM3, CM4 (4F18.0)

Card 41: CM5 (F18.0)

CM1-CM5 - coefficients for polynomial fit to subsonic nozzle contour.

NOTE: Include these cards only if ISUB = 1 (see Card 31).

Card 42: C, R, THETA1, THETA2 (4F10.0)

C - length, perpendicular to the throat plane, of the first section of the subsonic portion of the nozzle, in cm.

R - radius of the circular arc defining the second section of the nozzle, in cm.

THETA1 - angle orienting the first nozzle section in degrees. The first section of the nozzle is at an angle of (90-THETA1) to the nozzle throat plane.

THETA2 - angle orienting the second nozzle section in degrees. This section is a straight line, tangent to the circle at an angle of (90-THETA2) to the nozzle throat plane.

NOTE: Include these cards only if ISUB = 2 (see Card 31).

Card 43: N, X, EM, T (4F18.0)

Card 44: TVC1, TVC2, TVC3, TVN (4F18.0)

Card 45: TVH2, TVHH, P, A (4F18.0)

N - mach step value at which calculation is to be restarted.

X - X coordinate at which calculation is to be restarted (corresponds to N), in cm.

EM - Mach number at X.

T - gas temperature at X, in degrees Kelvin.

TVC1 - vibrational temperature at X of mode ν_1 of CO_2, in degrees Kelvin.

TVC2 - vibrational temperature at X of mode ν_2 of CO_2, in degrees Kelvin.

TVC3 - vibrational temperature at X of mode ν_3 of CO_2, in degrees Kelvin.

TVN - vibrational temperature at X of N_2, in degrees Kelvin.

TVH2 - vibrational temperature at X of mode ν_2 of H_2O, in degrees Kelvin.

TVHH - vibrational temperature at X of H_2, in degrees Kelvin.

P - static pressure at X, in atmospheres.

A - nozzle to throat area ratio at X.

NOTE: Include this card only if IRSTRT $\neq$ 0 (see Card 31).

This completes the input. Additional problems can be run by repeating Cards 1-41. To terminate, a card with 'STOP' is required.

SAMPLE CALCULATION

This section presents the results of a typical optimization problem. It utilizes virtually all features of the model except that weight and volume results are not used. This calculation maximizes the available specific energy of a CO/N_2O fuel/oxidizer device constrained to recover to atmospheric pressure. The design variables, constraints, and objective function are summarized in table 3. These choices are based on reference 2 and represent a reasonably advanced laser.

TABLE 3.- OPTIMIZATION PARAMETERS

Design variables

Variable	Initial value	Lower bound	Upper bound
Stagnation pressure, atm	60	25	115
Nozzle throat height, mm	.20	0.15	10
Nozzle area ratio	50	10	80
Mole fraction of H_2O	.005	.001	.05
Moles of N_2 to moles of C-N-O-H	8	3.5	15

TABLE 3.- Concluded

Constraints

Constraint	Initial value	Lower bound	Upper bound
Stagnation temperature, K	1338	1000	2100
Peak gain, $\%cm^{-1}$	1.32	1	5
Actual minus required pressure at end of diffuser (≥0 implies recovery)	314.5	0	1000

Objective function	Initial value	Final value
Maximum available specific energy	9.92 kJ/lb	16.00 kJ/lb

Shown below are the input data (fig. 2) and the resulting output (fig. 3) for this problem.

```
GDL OPTIMIZATION SAMPLE, JULY 1977
    2    5    5                1
    5   05    3    3    3                0
0.02       0.01

    5   16 1.0
25.0        115.0
0.15         10.0
10.0         80.0
0.001        0.05
3.5          15.0
    1    2 1.0
    2    3 1.0
    3    4 1.0
    4    6 1.0
    5   19 1.0
    3
    1          0 1000.     2100.0     1000.
   15          0 1.0       5.0        1.0
   34          0 0.0       1000.0     1000.0
END
 $OPTION BURNER=T, WEIGHT=T, VLCAV=F, LASER=T,  $END
 $SIZE  ETA=0.8,  EMEXIT=0.2,  $END
 $PROPER  CHI=0.,  O=0.,  R=8.,  S=0.,  KFUEL=1,  KOXID=2,  $END
1
2OPTIMUM GDL
N2O OXIDIZER
3
0
GDL OPTIMIZATION SAMPLE
1700.0     60.0       50.0       0.200      50.0       0.0
0.13       0.005      0.0        0.0
000600200
2.0        0.1628     4.37       0.         0.
STOP
**
```

Figure 2.- Data input.

```
CCCCCCC   OOOOOOO   PPPPPPP   EEEEEEE   SSSSSSS
C         O     O   P     P   E         S
C         O     O   P     P   E         S
C         O     O   PPPPPP    EEEE      SSSSSSS
C         O     O   P         E               S
C         O     O   P         E               S
CCCCCCC   OOOOOOO   P         EEEEEEE   SSSSSSS
```

N A S A - A M E S

C O N T R O L P R O G R A M

F O R

E N G I N E E R I N G S Y N T H E S I S

T I T L E

GDL OPTIMIZATION SAMPLE, JULY 1977

CARD IMAGES OF CONTROL DATA

```
CARD                    IMAGE

  1)  GDL OPTIMIZATION SAMPLE, JULY 1977
  2)      2    5    0                1
  3)      5   05    3    3    3                   0
  4)  0.02      0.01
  5)
  6)      5   16 1.0
  7)  25.0      115.0
  8)  0.15      10.0
  9)  10.0      80.0
 10)  0.001     0.05
 11)  3.5       15.0
 12)      1    2 1.0
 13)      2    3 1.0
 14)      3    4 1.0
 15)      4    6 1.0
 16)      5   16 1.0
 17)      3
 18)      1         0 1000.    2100.0     1000.
 19)     15         0 1.0      5.0        1.0
 20)     34         0 0.0      100.       10.
 21)  END
```

Figure 3.- Data output.

TITLE:
GDL OPTIMIZATION SAMPLE, JULY 1977

CONTROL PARAMETERS:

CALCULATION CONTROL,	NCALC =	2
NUMBER OF GLOBAL DESIGN VARIABLES,	NDV =	5
NUMBER OF SENSITIVITY VARIABLES,	NSV =	0
NUMBER OF FUNCTIONS IN TWO-SPACE,	N2VAR =	0
INPUT INFORMATION PRINT CODE,	IPNPUT =	0
SENSITIVITY PRINT CODE,	IPSENS =	1
TWO-SPACE PRINT CODE,	IP2VAR =	0
DEBUG PRINT CODE,	IPDBG =	0

CALCULATION CONTROL, NCALC
VALUE MEANING
1 SINGLE ANALYSIS
2 OPTIMIZATION
3 SENSITIVITY
4 OPTIMUM SENSITIVITY
5 TWO-VARIABLE FUNCTION SPACE
6 OPTIMUM TWO-VARIABLE FUNCTION SPACE

OPTIMIZATION INFORMATION

GLOBAL VARIABLE NUMBER 16 WILL BE MAXIMIZED

DESIGN VARIABLE INFORMATION
NON-ZERO INITIAL VALUE WILL OVER-RIDE MODULE INPUT

D. V. NO.	LOWER BOUND	UPPER BOUND	INITIAL VALUE
1	.25000E+02	.11500E+03	0.
2	.15000E+00	.10000E+02	0.
3	.10000E+02	.60000E+02	0.
4	.10000E-02	.60000E-01	0.
5	.35000E+01	.15000E+02	0.

DESIGN VARIABLES

ID	D. V. NO.	GLOBAL VAR. NO.	MULTIPLYING FACTOR
1	1	2	.10000E+01
2	2	3	.10000E+01
3	3	4	.10000E+01
4	4	6	.10000E+01
5	5	19	.10000E+01

CONSTRAINT INFORMATION

THERE ARE 3 CONSTRAINT SETS

ID	GLOBAL VAR. 1	GLOBAL VAR. 2	LINEAR ID	LOWER BOUND	UPPER BOUND	SCALE FACTOR
1	1	0	0	.10000E+04	.21000E+04	.10000E+04
3	15	0	0	.10000E+01	.50000E+01	.10000E+01
5	34	0	0	0.	.10000E+03	.10000E+02

TOTAL NUMBER OF CONSTRAINED PARAMETERS = 3

*****FLAME RESULTS*****

THE FUEL IS CO
THE OXIDIZER IS N2 O

CHI = 0.0000 Q = 0.0000 R = 8.0000 S = 0.0000 ETAN2 = 1.0000

REACTANTS

	MASS	MOLE
CARBON	0.0000	0.0000
CHON	.0946	.1000
N( )O( )	.1406	.1000
N2	.75[illegible]	.8000
CO2	0.0000	0.0000

PRODUCTS

	MASS	MOLE
CO2	.1486	.1000
H2O	0.0000	0.0000
O2	0.0000	0.0000
N2	.8514	.9000

FUEL-AIR RATIO = .1045 EXCESS AIR = 0.0000

FLAME TEMP = 1337.8936 DEG. K
DELNX = 0.000 DEG. K ADDITIONAL N2O ENTHALPY = 0. BTU/MOLE
DELN2 = 0.000 DEG.K ADDITIONAL ENTHALPY = 0. BTU/MOLE FOR 1.00 OF THE TOTAL NITROGEN

```
*****AVCO GAIN MODEL, NASA/AMES VERSION 2.0*****
      GDL OPTIMIZATION SAMPLE
      OPTIMUM GDL
      N2E OXIDIZER

                  NOZZLE THROAT HEIGHT (CM) =      .20000
                  NOMINAL RATE FOR PC2H

 TSTAG = 1337.39 DEG K      PSTAG =  60.0000 ATM      AEXIT/A* =  50.00      XMAX =   30.00      ANGLE =   0.00
 CO2 FRACTION =  .10000     H2O FRACTION =  .00500    CO FRACTION =  .00000  HE FRACTION = 0.00000   H2 FRACTION =  .00000
 N2 FRACTION =  .89500      J =  0    ITAUSB =  0     ITAUKT =  0  IFLUX =  0  ISUB =  6  IRATE =  0          IM2 =  1
 IPLOT =  3              IJ =  0   DFLX = 2.0000    ELSUB =  .103357 CM     ELNOZ =  4.37000 CM     SLOPE =  33.3567e3
 CURVE =   0.000000        NMAX =     100000        DXMAX =   .5000000      DXMIN =   .0001000000   DE.EST = 10.00
 C = 0.000000              RAL = 0.000000           THETA1 =  0.0000        THETA2 =  0.0000        FROZEN GAMMA =  1.39960040

 CM1 =   .1314568E+02      CM2 =   .6879339E+02     CM3 =   .1251436E+03    CM4 =  -.7642326E+02    CM5 =  -.3515258E+03
 THE STANDARD DEVIATION FOR THE CMS IS   0.000000    THE NUMBER OF POINTS TAKEN IS    0
 FRICTION FACTOR = 0.00000    FROZEN GAMMA =  1.29512    WEIGHTED GAS CONSTANT OF MIXTURE ERGS/GM-DEG K =  .28122E+07

 SWITCHOVER AT M = 1.050000    P/P* = 1.002020    X =  .00002 CM

 B1 =   .100E+01    B2 =   .500E+00    B3 =   .100E+01    B4 =   .143E+00    B5 =   .100E+01    B6 =   .100E+01
 B7 =   .100E+01    B8 =   .10E+01     B10=   .100E+01    B11=   .100E+01    B12=   .100E+01    B13=   .100E+01
 B14=   .100E+01

 TRANSITION LIFETIME =   .536E+01 SEC
 OPTICAL CROSS SECTIONS =  .170E-17 CM2 FOR CO2,    =  .370E-14 CM2 FOR N2,    =  .360E-14 CM2 FOR H2O,    =  .370E-14 CM2 FOR HE
```

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TG1(DEG K)	TG2(DEG K)	TG3(DEG K)	TR(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTG1/DX	DTG2/DX	DTG3/DX	DTR/DX	DTH2O/DX
N	U(CM/SEC)	EG1/R(DEG K)	EG2/R(DEG K)	EG3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LG2N	1/LG2G	1/LG2H	1/LG3N	1/LNH2	1/LG32N	1/LG32G	1/LG32H	1/LG2HE
1/LNHE	1/LG32HE	HST/R(DEG K)	TGO(DEG K)	EGO/R(DEG K)	DTGO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB C(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLUP(W/CM2)	MAX GAIN	J AT GMAX	PHI(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)	

-.10396E+00	.63413E-01	.91483E+01	.59331E+02	.13370E+04	.13370E+04	.13370E+04	.13370E+04	.13370E+04	.13370E+04
.10000E-03	-.13742E+01	.19729E+03	.72913E+01	.46520E+02	0.	0.	0.	0.	0.
0	.46002E+04	.59927E+02	.18260E+03	.29313E+02	.26609E+03	.25137E+01	.54065E+03	0.	.13561E+01
.18654E+00	.27101E+05	.50746E+05	.31930E+06	.29793E+05	.50537E+05	.77561E+04	.11202E+05	.12840E+05	.12117E+06
.11584E+06	.22848E+06	.52274E+04	.13370E+04	.34114E-17	0.	.13370E+04	.69067E-16	0.	
-.63957E-01	.73707E-01	.74775E+01	.59772E+02	.13367E+04	.13367E+04	.13367E+04	.13367E+04	.13366E+04	.13366E+04
.10000E-03	.13561E+01	-.14396E+03	-.83545E+01	-.42621E+02	-.42232E+02	-.42232E+02	-.42199E+02	-.41406E+02	-.41055E+02
200	.53463E+04	.59902E+02	.18274E+03	.29302E+02	.26594E+03	.25127E+01	.54040E+03	-.36856E+02	.11637E+01
.16008E+00	.23283E+05	.43597E+05	.27457E+06	.25605E+05	.43415E+05	.66630E+04	.96261E+04	.11043E+05	.12114E+06
.11577E+06	.22634E+06	.52274E+04	.13360E+04	.34046E-17	-.41464E+02	.13367E+04	.69996E-16	-.42621E+02	
-.63957E-01	.10051E+00	.57936E+01	.59578E+02	.13357E+04	.13356E+04	.13356E+04	.13356E+04	.13356E+04	.13356E+04
.10000E-03	.14472E+01	-.83375E+02	-.12109E+02	-.62429E+02	-.61007E+02	-.61007E+02	-.60928E+02	-.59106E+02	-.58346E+02
400	.72877E+04	.59819E+02	.18255E+03	.29243E+02	.26542E+03	.25069E+01	.53954E+03	-.52823E+02	.64627E+00
.11641E+00	.16995E+05	.31822E+05	.20102E+06	.18712E+05	.31635E+05	.48624E+04	.70316E+04	.80836E+04	.12105E+06
.11552E+06	.22805E+06	.52274E+04	.13356E+04	.34033E-17	-.59235E+02	.13357E+04	.68763E-16	-.62429E+02	
-.43957E-01	.15455E+00	.38000E+01	.59007E+02	.13327E+04	.13329E+04	.13329E+04	.13330E+04	.13332E+04	.13333E+04
.10000E-03	.49142E+01	-.11726E+03	-.62473E+02	-.33049E+03	-.30720E+03	-.30720E+03	-.30465E+03	-.27581E+03	-.26505E+03
600	.11193E+05	.59509E+02	.18201E+03	.29074E+02	.26400E+03	.24989E+01	.53717E+03	-.25361E+03	.53693E+00
.73847E-01	.10901E+05	.20411E+05	.13010E+06	.12040E+05	.20315E+05	.31163E+04	.45210E+04	.52423E+04	.12079E+06
.11480E+06	.22707E+06	.52274E+04	.13332E+04	.33861E-17	-.27830E+03	.13328E+04	.68071E-16	-.33041E+03	
-.17897E-01	.45717E+00	.14365E+01	.51967E+02	.12926E+04	.12965E+04	.12966E+04	.12966E+04	.13061E+04	.13081E+04
.24179E-03	.20652E+02	-.43232E+02	-.66936E+02	-.40776E+04	-.32982E+04	-.32982E+04	-.31693E+04	-.23566E+04	-.21253E+04
800	.32603E+05	.56618E+02	.17542E+03	.27047E+02	.24049E+03	.24005E+01	.51110E+03	-.23677E+04	.12954E+00
.17820E-01	.30634E+04	.57361E+04	.41359E+05	.35433E+04	.56733E+04	.88374E+03	.13119E+04	.16957E+04	.11724E+06
.10524E+06	.21407E+06	.52274E+04	.13055E+04	.32073E-17	-.24041E+04	.12928E+04	.59167E-16	-.40759E+04	
.10000E-04	.10004E+01	.10165E+01	.31495E+02	.11385E+04	.11896E+04	.11896E+04	.12016E+04	.12426E+04	.12451E+04
.10869E-05	.23909E+04	.28162E+01	-.87827E+05	-.90564E+06	-.88345E+04	-.88385E+04	-.73251E+04	-.41721E+04	-.51624E+04
848	.66967E+05	.47729E+02	.15470E+03	.21534E+02	.21660E+03	.21534E+01	.44277E+03	-.49071E+04	.14700E-01
.20221E-02	.66678E+03	.12485E+04	.15051E+05	.99113E+03	.11924E+04	.18413E+03	.32467E+03	.66459E+03	.10347E+06
.72534E+05	.16611E+06	.52275E+04	.12399E+04	.27553E-17	-.42117E+04	.11403E+04	.31732E-16	-.14347E+05	
.21956E-04	.10215E+01	.10169E+01	.30722E+02	.11304E+04	.11895E+04	.11895E+04	.12015E+04	.12426E+04	.12451E+04
.10869E-05	.11417E+04	.42326E+02	-.41522E+05	-.43461E+06	-.10365E+05	-.10365E+05	-.80283E+04	-.40159E+04	-.58300E+04
859	.68133E+05	.47720E+02	.15467E+03	.21573E+02	.21657E+03	.21561E+01	.44270E+03	-.53345E+04	.13349E-01
.16363E-02	.62646E+03	.11761E+04	.14600E+05	.94930E+03	.11212E+04	.17335E+03	.30413E+03	.64735E+03	.10274E+06
.71003E+05	.16589E+06	.52276E+04	.12390E+04	.27956E-17	-.37593E+04	.11324E+04	.30577E-16	-.43222E+06	

A/A* AT SWITCHOVER CHANGED FROM .10169E+01 TO .10020E+01 TO MATCH REQUIRED EXIT AREA. CORRESPONDING ATHROAT/A* = .98141E+01

.21956E-04	.10215E+01	.10020E+01	.30722E+02	.11304E+04	.11895E+04	.11895E+04	.12015E+04	.12426E+04	.12451E+04
.10000E-03	.26034E+04	.93341E+02	-.34643E+05	-.99208E+06	-.10365E+05	-.10365E+05	-.80283E+04	-.40159E+04	-.58300E+04
859	.68133E+05	.47720E+02	.15467E+03	.21573E+02	.21657E+03	.21561E+01	.44270E+03	-.53345E+04	.13349E-01
.13363E-02	.62846E+03	.11761E+04	.14600E+05	.94930E+03	.11212E+04	.17335E+03	.30413E+03	.64735E+03	.10274E+06
.71003E+05	.16589E+06	.52276E+04	.12390E+04	.27956E-17	-.37593E+04	.11324E+04	.30577E-16	-.43222E+06	
-.44182E-04	-.44175E-04						.10000E+01	.10000E+01	.97023E-02

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TG1(DEG K)	TG2(DEG K)	TG3(DEG K)	.N(DEG K)	TH20(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTG1/DX	DTG2/DX	DTG3/DX	DTH/DX	DTH20/DX
N	U(CM/SEC)	EG1/R(DEG K)	EG2/R(DEG K)	EG3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVIBF/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNG	1/LG2N	1/LG2G	1/LG2M	1/LG3N	1/LNH2	1/LG32N	1/LG32G	1/LG32M	1/LG2HE
1/LNHE	1/LG32HE	HST/R(DEG K)	TGG(DEG K)	EGO/R(DEG K)	DTGG/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB G(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLUP(W/CM2)	MAX GAIN	J/LB GMAX	J AT GMAX	PH2(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)
.20161E+01	.51183E+01	.42048E+02	.55513E-01	.22945E+03	.37702E+03	.37702E+03	.11320E+04	.11735E+04	.3[illegible]5E+03
.54920E-01	.21899E+00	.92572E+01	-.13483E-01	-.15910E+02	-.76185E+02	-.76185E+02	-.54604E+01	-.34[illegible]14E+01	-.50841E+02
1031	.15381E+06	.11866E+01	.16327E+02	.17976E+02	.18282E+03	.36451E-01	.21[illegible]35E+03	-.12564E+02	.16156E-11
.22224E-12	.20273E-01	.37960E-01	.18208E+03	.88982E+01	.25260E-02	.13729E-01	.4[illegible]633E-01	.45971E+01	.24386E+07
.97062E+02	.25082E+05	.52[illegible]5E+04	.1350[illegible]E+04	.35019E-17	.20584E+02	-.16676+258	.5[illegible]00E-03	-.51303E+03	
.60077E-03	.55633E-03	.33371E+03	.10665E-01	.95296E+04	13		.9[illegible]482E+00	.99477E+00	.10268E-03
.40498E+01	.52714E+01	.49[illegible]3E+02	.52264E-01	.21892E+03	.28335E+03	.28335E+03	.11251E+04	.11673E+04	.32789E+03
.64851E-01	-.15775E-01	.95646E-01	.21462E-03	.12640E+01	-.24956E+02	-.24958E+02	-.20676E+01	-.25[illegible]7E+01	-.25439E+02
1064	.15474E+06	.21929E+00	.67116E+01	.17630E+02	.18013E+03	.10460E-01	.2047[illegible]E+03	-.352[illegible]4E+01	.69[illegible]07E-12
.96165E-13	.15151E-01	.28370E-01	.15420E+03	.75663E+01	.15783E-02	.10855E-01	.3[illegible]004E-01	.40692E+01	.23756E+07
.74871E+02	.25194E+05	.522[illegible]5E+04	.13[illegible]51E+04	.37304E-17	.15086E+02	-.16876+253	.59[illegible]00E-03	.12527E+02	
.75459E-03	.74124E-03	.299[illegible]6E+03	.13036E-01	.10121E+05	13		.9[illegible]406E+00	.[illegible]8401E+00	.[illegible]6017E-04
.60637E+01	.52457E+01	.50000E+02	.52736E-01	.22053E+03	.25473E+03	.25473E+03	.11209E+04	.11627E+04	.28[illegible]53E+03
.65056E-01	-.88351E-[illegible]2	0.	.17312E-03	.70626E+00	-.66629E+01	-.66629E+01	-.21343E+01	-.24[illegible]1E+01	-.14072E+02
1095	.15470E+06	.10255E+00	.45405E+01	.17423E+02	.17774E+03	.40814E-02	.1[illegible]581E+03	-.174[illegible]6E+01	.79210E-12
.10896E-12	.15459E-01	.28947E-01	.15371E+03	.75367E+01	.16672E-02	.10956E-01	.3[illegible]2c1E-01	.40[illegible]64E+01	.23671E+07
.78673E+02	.25162E+05	.522[illegible]5E+04	.14140E+04	.39260E-17	.13609E+02	-.16876+256	.59[illegible]00E-03	.90426E+01	
.76073E-03	.74732E-03	.298[illegible]4E+03	.13135E-01	.10072E+05	13		.9[illegible]407E+00	.9[illegible]402E+00	.86025E-04
.80823E+01	.52315E+01	.50000E+02	.53035E-01	.22210E+03	.24734E+03	.24734E+03	.11165E+04	.11577E+04	.26316E+03
.65177E-01	-.67124E-02	0.	.13263E-03	.54094E+00	-.13207E+01	-.13207E+01	-.21660E+01	-.24610E+01	-.57667E+01
1126	.15468E+06	.[illegible]3256E-01	.40823E+01	.17209E+02	.17541E+03	.22736E-02	.1[illegible]679E+03	-.133[illegible]2E+01	.35554E-12
.11769E-12	.15456E-01	.29314E-01	.15343E+03	.75131E+01	.17246E-02	.11024E-01	.3[illegible]457E-01	.40375E+01	.23[illegible]43E+07
.81120E+02	.25145E+05	.522[illegible]5E+04	.14401E+04	.41051E-17	.12225E+02	-.16876+259	.55[illegible]00E-03	.7346[illegible]E+01	
.75081E-03	.73758E-03	.29507E+03	.13043E-01	.99541E+04	13		.9[illegible]407E+00	.9[illegible]403E+00	.86037E-04
.10104E+02	.52186E+01	.50000E+02	.53292E-01	.22315E+03	.24686E+03	.24686E+03	.11121E+04	.11527E+04	.26226E+03
.65282E-01	-.61727E-02	0.	.12265E-03	.50[illegible]9E+00	-.43076E-01	-.43076E-01	-.21696E+01	-.24473E+01	-.16875E+01
1157	.15465E+06	.6049[illegible]9E-01	.40124E+01	.16955E+02	.17311E+03	.18171E-02	.1[illegible]420E+03	-.12400E+01	.31351E-12
.12566E-12	.15[illegible]25E-01	.29632E-01	.15318E+03	.75040E+01	.17749E-02	.11081E-01	.3[illegible]607E-01	.4106[illegible]E+01	.24005E+07
.83255E+02	.25132E+05	.522[illegible]5E+04	.14635E+04	.42679E-17	.10533E+02	-.16876+254	.5[illegible]00E-03	.[illegible]2761E+01	
.73779E-03	.72460E-03	.29126E+03	.12850E-01	.98255E+04	13		.9[illegible]405E+00	.9[illegible]403E+00	.[illegible]6045E-04
.12130E+02	.52063E+01	.50000E+02	.53537E-01	.22415E+03	.24712E+03	.24712E+03	.11077E+04	.11473E+04	.26060E+03
.65363E-01	-.59819E-02	0.	.11087E-03	.46862E+00	.23392E+00	.23392E+00	-.21670E+01	-.24373E+01	-.25177E+00
1188	.15464E+06	.[illegible]1143E-01	.40281E+01	.16[illegible]1E+02	.17083E+03	.17[illegible]3E-02	.1[illegible]173E+03	-.12055E+01	.97231E-12
.13375E-12	.15990E-01	.29940E-01	.15235E+03	.74815E+01	.18242E-02	.11136E-01	.3[illegible]752E-01	.4115[illegible]E+01	.24065E+07
.85338E+02	.25121E+05	.522[illegible]5E+04	.14944E+04	.44143E-17	.97270E+01	-.16876+255	.5[illegible]00E-03	.[illegible]0112E+01	
.72430E-03	.71156E-03	.28740E+03	.12641E-01	.98954E+04	13		.9[illegible]404E+00	.9[illegible]404E+00	.86055E-04
.14158E+02	.51943E+01	.50000E+02	.53772E-01	.22513E+03	.24767E+03	.24767E+03	.11034E+04	.11423E+04	.26059E+03
.65482E-01	-.58687E-02	0.	.11439E-03	.43247E+00	.23496E+00	.23496E+00	-.21624E+01	-.24[illegible]0E+01	.15506E+00
1219	.15462E+06	.[illegible]2561E-01	.40[illegible]4E+01	.16566E+02	.16857E+03	.17177E-02	.1[illegible]529E+03	-.11943E+01	.10335E-11
.14217E-12	.16153E-01	.30246E-01	.15271E+03	.74753E+01	.18736E-02	.11191E-01	.3[illegible]593E-01	.41247E+01	.24124E+07
.87428E+02	.25111E+05	.522[illegible]5E+04	.15030E+04	.45466E-17	.85969E+01	-.16876+256	.5[illegible]00E-03	.90115E+01	
.71090E-03	.69639E-03	.28[illegible]56E+03	.12432E-01	.[illegible]565[illegible]E+04	13		.9[illegible]410E+00	.9[illegible]405E+00	.86063E-04

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TC1(DEG K)	TC2(DEG K)	TC3(DEG K)	TN(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTC1/DX	DTC2/DX	DTC3/DX	DTN/DX	DTH2O/DX
N	U(CM/SEC)	EC1/R(DEG K)	EC2/R(DEG K)	EC3/R(DEG K)	EH/R(DEG K)	EH2O/R(DEG K)	EWTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LC2N	1/LC2C	1/LC2H	1/LC3N	1/LNH2	1/LC32H	1/LC32C	1/LC32H	1/LC2HE
1/LNHE	1/LC32HE	HST/R(DEG K)	TCO(DEG K)	ECO/R(DEG K)	DTCO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB D(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLJP(W/CM2)	MAX GAIN	J/LB GMAX	J AT GMAX	PHI(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)
.16189E+02	.51825E+01	.50000E+02	.54018E-01	.22611E+03	.24829E+03	.24829E+03	.10290E+04	.11379E+04	.26103E+03
.65581E-01	-.57734E-02	0.	.11724E-03	.47767E+00	.30704E+00	.30704E+00	-.21562E+01	-.24103E+01	.26321E+00
1250	.15460E+06	.64162E-01	.41049E+01	.16357E+02	.16633E+03	.17439E-02	.16688E+03	-.11623E+01	.10976E-11
.15099E-12	.16316E-01	.30551E-01	.15240E+03	.74612E+01	.19240E-02	.11245E-01	.40034E-01	.41334E+01	.24132E+07
.89535E+02	.25103E+05	.522[illegible]5E+04	.15193E+04	.46636E-17	.75363E+01	-.16876+258	.5[illegible]00E-03	.10[illegible]0E+02	
.69769E-03	.68542E-03	.27974E+03	.12226E-01	.94371E+04	13		.3[illegible]410E+00	.98405E+00	.86079E-04
.18224E+02	.51703E+01	.50000E+02	.54255E-01	.22707E+03	.24891E+03	.24891E+03	.10946E+04	.11330E+04	.26160E+03
.65679E-01	-.56830E-02	0.	.11615E-03	.47315E+00	.30833E+00	.30833E+00	-.21534E+01	-.24056E+01	.26937E+00
1281	.15458E+06	.85817E-01	.41455E+01	.16147E+02	.16410E+03	.17776E-02	.13446E+03	-.11711E+01	.11647E-11
.16021E-12	.16480E-01	.30854E-01	.15225E+03	.74473E+01	.19748E-02	.11300E-01	.40173E-01	.41420E+01	.24241E+07
.91562E+02	.25096E+05	.522 5E+04	.15336E+04	.47666E-17	.65401E+01	-.16876+25[illegible]	.5[illegible]00E-03	.11[illegible]2E+02	
.69471E-03	.67267E-03	.275[illegible]4E+03	.12022E-01	.93093E+04	13		.9[illegible]411E+00	.9[illegible]406E+00	.86069E-04
.20262E+02	.51593E+01	.50000E+02	.54481E-01	.22803E+03	.24954E+03	.24954E+03	.10[illegible]02E+04	.11281E+04	.26220E+03
.65777E-01	-.55946E-02	0.	.11509E-03	.46869E+00	.30720E+00	.30720E+00	-.21481E+01	-.24003E+01	.29354E+00
1312	.15457E+06	.87495E-01	.41672E+01	.15939E+02	.16189E+03	.18134E-02	.13211E+03	-.11600E+01	.12349E-11
.16987E-12	.16643E-01	.31164E-01	.15203E+03	.74335E+01	.20262E-02	.11355E-01	.40311E-01	.41505E+01	.24293E+07
.93810E+02	.25089E+05	.522 5E+04	.15460E+04	.48560E-17	.56039E+01	-.16876+25[illegible]	.5[illegible]00E-03	.13159E+02	
.67195E-03	.66014E-03	.27219E+03	.11820E-01	.91024E+04	13		.9[illegible]412E+00	.98407E+00	.86099E-04
.22302E+02	.51460E+01	.50000E+02	.54724E-01	.22696E+03	.25017E+03	.25017E+03	.10[illegible]5E+04	.11232E+04	.26260E+03
.65875E-01	-.55076E-02	0.	.11402E-03	.46423E+00	.30546E+00	.30546E+00	-.21431E+01	-.23[illegible]09E+01	.29165E+00
1343	.15455E+06	.89137E-01	.42265E+01	.15732E+02	.15970E+03	.18[illegible]5E-02	.17375E+03	-.11[illegible]E+01	.13063E-11
.17996E-12	.16807E-01	.31471E-01	.15100E+03	.74197E+01	.20783E-02	.11410E-01	.40446E-01	.4156[illegible]E+01	.24358E+07
.95978E+02	.25084E+05	.522 5E+04	.15565E+04	.49325E-17	.47241E+01	-.16876+256	.5[illegible]00E-03	.14415E+02	
.65941E-03	.64782E-03	.26845E+03	.11622E-01	.90565E+04	13		.3[illegible]412E+00	.[illegible]40[illegible]E+00	.86109E-04
.24346E+02	.51369E+01	.50000E+02	.54956E-01	.22993E+03	.25079E+03	.25079E+03	.10[illegible]14E+04	.111[illegible]8E+04	.26339E+03
.65972E-01	-.54210E-02	0.	.11235E-03	.45977E+00	.30360E+00	.30360E+00	-.21377E+01	-.23[illegible]14E+01	.28570E+00
1374	.15453E+06	.90913E-01	.42693E+01	.15526E+02	.15753E+03	.18[illegible]66E-02	.17742E+03	-.11379E+01	.13849E-11
.19051E-12	.16972E-01	.31774E-01	.15156E+03	.74062E+01	.21[illegible]9E-02	.11465E-01	.40[illegible]4E-01	.41672E+01	.24415E+07
.98165E+02	.25080E+05	.522 5E+04	.15653E+04	.49967E-17	.[illegible]9977E+01	-.16[illegible]+25[illegible]	.5[illegible]00E-03	.15762E+02	
.64709E-03	.63573E-03	.26474E+03	.11426E-01	.89316E+04	13		.3[illegible]413E+00	.[illegible]40[illegible]E+00	.86119E-04
.26392E+02	.51258E+01	.50000E+02	.55186E-01	.23067E+03	.25141E+03	.25141E+03	.10771E+04	.11135E+04	.26395E+03
.66068E-01	-.53171E-02	0.	.11186E-03	.45531E+00	.30162E+00	.30162E+00	-.21322E+01	-.23715E+01	.28511E+00
1405	.15451E+06	.92645E-01	.43112E+01	.15321E+02	.15537E+03	.19235E-02	.17510E+03	-.11267E+01	.14650E-11
.20152E-12	.17137E-01	.32066E-01	.15136E+03	.73927E+01	.21342E-02	.11520E-01	.40715E-01	.41754E+01	.24473E+07
.10037E+03	.25077E+05	.522[illegible]5E+04	.15725E+04	.50492E-17	.31219E+01	-.16876+25[illegible]	.5[illegible]00E-03	.17265E+02	
.63499E-03	.62354E-03	.26106E+03	.11232E-01	.88077E+04	13		.3[illegible]414E+00	.[illegible]40[illegible]E+00	.86129E-04
.28442E+02	.51150E+01	.50000E+02	.55415E-01	.23173E+03	.25203E+03	.25203E+03	.10727E+04	.110[illegible]6E+04	.26456E+03
.66164E-01	-.52536E-02	0.	.11081E-03	.45014E+00	.29959E+00	.29959E+00	-.21265E+01	-.23621E+01	.28143E+00
1436	.15450E+06	.94362E-01	.43826E+01	.15115E+02	.15323E+03	.19606E-02	.17240E+03	-.11156E+01	.15405E-11
.21301E-12	.17300E-01	.323[illegible]3E-01	.15114E+03	.73783E+01	.22331E-02	.11575E-01	.40[illegible]52E-01	.41835E+01	.24531E+07
.10260E+03	.25075E+05	.522 5E+04	.15781E+04	.50906E-17	.23544E+01	-.16876+25[illegible]	.5[illegible]00E-03	.1[illegible]74[illegible]E+02	
.62310E-03	.61216E-03	.25742E+03	.11045E-01	.86711E+04	15		.3[illegible]414E+00	.9[illegible]410E+00	.86136E-04

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TC1(DEG K)	TC2(DEG K)	TC3(DEG K)	TN(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTC1/DX	DTC2/DX	DTC3/DX	DTN/DX	DTH2O/DX
N	U(CM/SEC)	EC1/R(DEG K)	EC2/R(DEG K)	EC3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LC2N	1/LC2C	1/LC2H	1/LC3N	1/LNH2	1/LC32N	1/LC32C	1/LC32H	1/LC2HE
1/LNHE	1/LC32HE	HST/R(DEG K)	TCO(DEG K)	ECO/R(DEG K)	DTCO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB C(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLJP(W/CM2)	MAX GAIN	J/LB GMAX	J AT GMAX	PHI(W/CM2)	DCP FAC P	DCP FAC R	DENS(G/CM3)
.30031E+02	.51067E+01	.50000E+02	.55590E-01	.23251E+03	.25250E+03	.25250E+03	.10693E+04	.11049E+04	.26500E+03
.66239E-01	-.51897E-02	0.	.10997E-03	.48737E+00	.29797E+00	.23757E+00	-.21220E+01	-.23546E+01	.27657E+00
1460	.15449E+06	.95754E-01	.43846E+01	.14962E+02	.15159E+03	.19893E-02	.17104E+03	-.11069E+01	.16156E-11
.22224E-12	.17427E-01	.32632E-01	.15097E+03	.73691E+01	.22801E-02	.11616E-01	.40955E-01	.41897E+01	.24575E+07
.10433E+03	.25074E+05	.52265E+04	.15315E+04	.51155E-17	.18629E+01	-.16876+252	.59600E-03	.20013E+02	
.61403E-03	.60326E-03	.25461E+03	.10904E-01	.65765E+04	15		.93415E+00	.92410E+00	.36146E-04

***** OPTIMUM GDL *****
***** N2O OXIDIZER *****

GDL OPTIMIZATION SAMPLE

THE MAXIMUM GAIN IS .13163E+01 PCT/CM THIS OCCURS AT X = 6.06371 CM

THERE IS NO VALUE OF GAIN SUITABLE FOR THE REQUIRED CONDITION

THE NUMBER CHARACTERIZING THE TRAILING PORTION OF THE CURVE IS .3124671
THE NUMBER CHARACTERIZING THE CURVATURE OF THE TRAILING PORTION OF THE CURVE IS .4947424
THE NUMBER AVERAGE SLOPE IS -.00953

THE AVERAGE SPECIFIC POWER OVER A 10.000 CM DISTANCE IS 3913.2470 J/LB.
IT WAS AVERAGED BETWEEN 2.016 CM AND 12.016 CM.

ORIGINAL PAGE IS
OF POOR QUALITY

WEIGHT/VOLUME RESULTS

TOTAL PRESSURE (PSI)	862.00	STAGNATION TEMPERATURE (DEGREES KELVIN)	1337.59
TOTAL POWER (WATTS)	500000.00	SPECIFIC POWER (JOULES/LBM)(EFF = 1.00)	9913.25
NUMBER OF SHOTS	19	SHOT LENGTH (SECONDS/FIRING)	2.00
TOTAL FLOW TIME (SECONDS)	40.80	MASS FLOW RATE (LBM/SECOND)	50.41
LASER AND MIRROR HEIGHT (INCHES)	5.00	LASER WIDTH (INCHES)	71.07
CAVITY ASPECT RATIO	14.21	NOZZLE BOUNDRY LAYER FACTOR	.965417E-05
DIFFUSER LENGTH (INCHES)	6.49	REQUIRED DIFFUSER ENTRANCE PRESSURE (PSI)	623.30
DIFFUSER EXIT MACH NUMBER	.20	DIFFUSER EXIT PRESSURE (PSI)	14.70

SYSTEM AND SUBSYSTEM WEIGHTS AND VOLUMES

	WEIGHT (LB)	VOLUME (FT**3)
*COMBUSTOR	120.46	3.965
*CAVITY, NOZZLE, MANIFOLD	413.95	5.142
SIDEWALL	112.05	
NOZZLE	224.11	
ENDWALL	60.00	
MANIFOLD	17.79	
*STRUCTURE	103.69	
*MOUNTS	41.60	
*DIFFUSER (ETA = .80)	462.72	1.335
VANES (55)	133.30	
SIDEWALLS	27.03	
ENDWALLS	320.54	
MOUNTS	11.25	
*OPTICAL BENCH	36.07	9.924
*ADVANCED OPTICAL BENCH	500.00	10.000
*FUEL SUPPLY SYSTEM	2376.41	120.151
FUEL	2057.46	41.745
TANK	62.62	
PUMP	126.02	4.033
VALVE	100.31	33.313
*MISCELLANEOUS	351.00	16.000
TOTAL	3936.10	156.562
TOTAL USING ADVANCED BENCH	4400.03	156.683

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                    C O N M I N

          FORTRAN PROGRAM FOR

     CONSTRAINED FUNCTION MINIMIZATION

NASA/AMES RESEARCH CENTER, MOFFETT FIELD, CALIF.

          VERSION 1I     JULY, 1975
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CONSTRAINED FUNCTION MINIMIZATION

CONTROL PARAMETERS

IPRINT	NDV	ITMAX	NCON	NSIDE	ICNDIR	NSCAL	MFDG
5	5	5	6	1	3	3	0

LINOBJ	ITRM	N1	N2	N3	N4	N5
0	3	7	16	7	7	14

CT	CTMIN	CTL	CTLMIN
-.50000E-01	.40000E-02	-.10000E-01	.10000E-02

THETA	PHI	DELFUN	DABFUN
.10000E+01	.50000E+01	.10000E-02	.95192E+01

FDCH	FDCHM
.20000E-01	.10000E-01

LOWER BOUNDS ON DECISION VARIABLES (VLB)

1)	.25000E+02	.15000E+00	.10000E+02	.10000E-02	.35000E+01

UPPER BOUNDS ON DECISION VARIABLES (VUB)

1)	.11500E+03	.10000E+02	.80000E+02	.50000E-01	.15000E+02

ALL CONSTRAINTS ARE NON-LINEAR

INITIAL FUNCTION INFORMATION

OBJ = -.391925E+04

DECISION VARIABLES (X-VECTOR)

1)	.60000E+02	.20000E+00	.50000E+02	.50000E-02	.30000E+01

CONSTRAINT VALUES (G-VECTOR)

1)	-.33789E+00	-.76211E+00	-.31888E+00	-.36811E+01	-.25670E+02	.15170E+02

```
BEGIN ITERATION NUMBER     1

CT =   -.50000E-01     CTL =   -.10000E-01     PHI =    .50000E+01

NEW SCALING VECTOR (SCAL)
  .6000E+02    .2000E+00    .5000E+02    .5000E-02    .2000E+01

THERE ARE     0 ACTIVE CONSTRAINTS

THERE ARE     1 VIOLATED CONSTRAINTS
CONSTRAINT NUMBERS ARE
     6

THERE ARE     0 ACTIVE SIDE CONSTRAINTS

GRADIENT OF OBJ
  1)     .21294E+04   .74930E+03  -.13810E+04   .52204E+03   .10786E+05

GRADIENTS OF ACTIVE AND VIOLATED CONSTRAINTS
CONSTRAINT NUMBER     6
  1)     .82709E+02  -.35049E+01  -.66339E+02  -.51365E-01  -.43752E+02


PUSH-OFF FACTORS, (THETA(I), I=1,NAC)
  1)     .10000E+01

CONSTRAINT PARAMETER, BETA =     .11783E+01

SEARCH DIRECTION (S-VECTOR)
  1)    -.10000E+01   .55741E-02   .73774E+00  -.22316E-01   .68013E-02

ONE-DIMENSIONAL SEARCH
INITIAL SLOPE =  -.3151E+04  PROPOSED ALPHA =    .1173E+00



* * CONSTRAINED ONE-DIMENSIONAL SEARCH INFORMATION * * *


  PROPOSED DESIGN
  ALPHA =  .11731E+00
  X-VECTOR
 .5296E+02    .2001E+00    .5462E+02    .4987E-02    .8006E+01

  OBJ =  -.10314E+05

  CONSTRAINT VALUES
-.3373E+00  -.7627E+00  -.3649E+00  -.3635E+01  -.1036E+02   .3645E+00

  TWO-POINT INTERPOLATION


  PROPOSED DESIGN
  ALPHA =  .12007E+00
  X-VECTOR
 .5290E+02    .2001E+00    .5473E+02    .4987E-02    .8007E+01

  OBJ =  -.10324E+05

  CONSTRAINT VALUES
-.3373E+00  -.7627E+00  -.3666E+00  -.3633E+01  -.1000E+02   .3639E-02

  * * * END OF ONE-DIMENSIONAL SEARCH
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CALCULATED ALPHA =     .12007E+00

OBJ =    -.103240E+05

DECISION VARIABLES (X-VECTOR)
  1)      .52796E+02    .20013E+00    .54729E+02    .49866E-02    .30065E+01

CONSTRAINT VALUES (G-VECTOR)
  1)     -.33729E+00   -.76271E+00   -.36659E+00   -.36334E+01   -.10004E+02    .36392E-02



BEGIN ITERATION NUMBER     2

CT =    -.50000E-01     CTL =    -.10000E-01     PHI =     .50000E+01

THERE ARE     1 ACTIVE CONSTRAINTS
CONSTRAINT NUMBERS ARE
     6

THERE ARE     0 VIOLATED CONSTRAINTS

THERE ARE     0 ACTIVE SIDE CONSTRAINTS

GRADIENT OF OBJ
  1)      .24555E+04    .72195E+03   -.12688E+04    .43286E+03    .11853E+05

GRADIENTS OF ACTIVE AND VIOLATED CONSTRAINTS
CONSTRAINT NUMBER     6
  1)      .78156E+02   -.43545E+01   -.63375E+02   -.14110E+01   -.50233E+02

PUSH-OFF FACTORS, (THETA(I), I=1,NAC)
  1)      .11509E+01

CONSTRAINT PARAMETER, BETA =     .77271E+00

SEARCH DIRECTION (S-VECTOR)
  1)     -.10000E+01   -.17716E-01    .74912E+00   -.22751E-01   -.50613E+00

ONE-DIMENSIONAL SEARCH
INITIAL SLOPE =   -.9431E+04  PROPOSED ALPHA =    .5474E-01



* * CONSTRAINED ONE-DIMENSIONAL SEARCH INFORMATION * * *

 PROPOSED DESIGN
 ALPHA =  .54736E-01
 X-VECTOR
.4951E+02    .1909E+00    .5673E+02    .4980E-02    .7785E+01

 OBJ =  -.10847E+05

 CONSTRAINT VALUES
-.3582E+00   -.7418E+00   -.4122E+00   -.3589E+01   -.4747E+01   -.5253E+01

 TWO-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =  .10416E+00
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 X-VECTOR
 .4655E+02   .1998E+00   .5863E+02   .4975E-02   .7585E+01

 OBJ =  -.11319E+05

 CONSTRAINT VALUES
-.3779E+00  -.7221E+00  -.4457E+00  -.3554E+01  -.3530E+00  -.9647E+01

 THREE-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =  .10830E+00
 X-VECTOR
 .4630E+02   .1998E+00   .5879E+02   .4974E-02   .7561E+01

 OBJ =  -.11352E+05

 CONSTRAINT VALUES
-.3796E+00  -.7204E+00  -.4476E+00  -.3552E+01  -.1151E+00  -.9585E+01

 * * * END OF ONE-DIMENSIONAL SEARCH

 CALCULATED ALPHA =    .10830E+00

 OBJ =   -.113519E+05

 DECISION VARIABLES (X-VECTOR)
   1)     .46298E+02   .19975E+00   .58786E+02   .49743E-02   .75680E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.37958E+00  -.72042E+00  -.44764E+00  -.35524E+01  -.11503E+00  -.95849E+01


 BEGIN ITERATION NUMBER    3

 CT =   -.50000E-01     CTL =   -.10000E-01     PHI =    .50000E+02

 THERE ARE    0 ACTIVE CONSTRAINTS

 THERE ARE    0 VIOLATED CONSTRAINTS

 THERE ARE    0 ACTIVE SIDE CONSTRAINTS

 GRADIENT OF OBJ
   1)     .21386E+04   .65462E+03  -.12761E+04   .34363E+03   .12502E+05

 SEARCH DIRECTION (S-VECTOR)
   1)    -.17106E+00  -.52361E-01   .10207E+00  -.27485E-01  -.10000E+01

 ONE-DIMENSIONAL SEARCH
 INITIAL SLOPE =  -.1304E+05  PROPOSED ALPHA =   .6108E-01



* * CONSTRAINED ONE-DIMENSIONAL SEARCH INFORMATION * * *

 PROPOSED DESIGN
 ALPHA =  .61089E-01
 X-VECTOR
 .4567E+02   .1991E+00   .5910E+02   .4986E-02   .7073E+01
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 OBJ =  -.12200E+05

 CONSTRAINT VALUES
-.4315E+00  -.6685E+00  -.5004E+00  -.3500E+01  -.2823E+01  -.7177E+01

 TWO-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =  .22297E+00
 X-VECTOR
.4401E+02   .1974E+00   .5992E+02   .4944E-02   .5784E+01

 OBJ =  -.14254E+05

 CONSTRAINT VALUES
-.5958E+00  -.5042E+00  -.5057E+00  -.3494E+01  -.1181E+02   .1609E+01

 THREE-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =  .19387E+00
 X-VECTOR
.4431E+02   .1977E+00   .5978E+02   .4946E-02   .6017E+01

 OBJ =  -.13941E+05

 CONSTRAINT VALUES
-.5617E+00  -.5383E+00  -.5277E+00  -.3472E+01  -.1002E+02   .1924E-01

 * * * END OF ONE-DIMENSIONAL SEARCH

 CALCULATED ALPHA =    .61089E-01

 OBJ =   -.121995E+05

 DECISION VARIABLES (X-VECTOR)
   1)     .45671E+02   .19511E+00   .59097E+02   .49659E-02   .70793E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.43146E+00  -.66854E+00  -.50044E+00  -.34996E+01  -.28234E+01  -.71766E+01



 BEGIN ITERATION NUMBER    4

 CT =   -.50000E-01     CTL =   -.10000E-01     PHI =    .50000E+02

 NEW SCALING VECTOR (SCAL)
   .4567E+02    .1931E+00    .5910E+02    .4966E-02    .7079E+01

 THERE ARE     0 ACTIVE CONSTRAINTS

 THERE ARE     0 VIOLATED CONSTRAINTS

 THERE ARE     0 ACTIVE SIDE CONSTRAINTS

 GRADIENT OF OBJ
   1)     .21913E+04   .76237E+03  -.15397E+04   .31390E+03   .11618E+05

 SEARCH DIRECTION (S-VECTOR)
   1)    -.13542E+00  -.64550E-01   .13026E+00  -.26561E-01  -.10000E+01
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 ONE-DIMENSIONAL SEARCH
 INITIAL SLOPE =  -.1245E+05  PROPOSED ALPHA =    .8514E-01



* * CONSTRAINED ONE-DIMENSIONAL SEARCH INFORMATION * * *

  PROPOSED DESIGN
  ALPHA =  .85137E-01
  X-VECTOR
 .4495E+02   .1980E+00   .5975E+02   .4955E-02   .6477E+01

  OBJ =  -.13251E+05

  CONSTRAINT VALUES
-.5037E+00  -.5963E+00  -.5391E+00  -.3461E+01  -.6684E+01  -.3336E+01

  TWO-POINT INTERPOLATION


  PROPOSED DESIGN
  ALPHA =  .16161E+00
  X-VECTOR
 .4430E+02   .1970E+00   .6034E+02   .4945E-02   .5935E+01

  OBJ =  -.14081E+05

  CONSTRAINT VALUES
-.5735E+00  -.5265E+00  -.5265E+00  -.3473E+01  -.1038E+02   .3603E+00

  THREE-POINT INTERPOLATION


  PROPOSED DESIGN
  ALPHA =  .15455E+00
  X-VECTOR
 .4436E+02   .1971E+00   .6025E+02   .4946E-02   .5985E+01

  OBJ =  -.14006E+05

  CONSTRAINT VALUES
-.5663E+00  -.5337E+00  -.5302E+00  -.3470E+01  -.1006E+02   .2677E-02

  * * * END OF ONE-DIMENSIONAL SEARCH

  CALCULATED ALPHA =    .15455E+00

  OBJ =   -.140057E+05

  DECISION VARIABLES (X-VECTOR)
    1)     .44362E+02   .19712E+00   .60237E+02   .49455E-02   .59352E+01

  CONSTRAINT VALUES (G-VECTOR)
    1)    -.56625E+00  -.53375E+00  -.53022E+00  -.34696E+01  -.10003E+02   .26773E-02



  BEGIN ITERATION NUMBER    5

  CT =   -.50000E-01     CTL =   -.10000E-01     PHI =    .50000E+02

  THERE ARE    1 ACTIVE CONSTRAINTS
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 CONSTRAINT NUMBERS ARE
     6

 THERE ARE     0 VIOLATED CONSTRAINTS

 THERE ARE     0 ACTIVE SIDE CONSTRAINTS

 GRADIENT OF OBJ
   1)      .23161E+04   .88281E+03  -.23661E+04   .13966E+03   .10241E+05

 GRADIENTS OF ACTIVE AND VIOLATED CONSTRAINTS
 CONSTRAINT NUMBER     6
   1)      .55538E+02  -.66882E+01  -.43877E+02  -.31770E+01  -.59400E+02

 PUSH-OFF FACTORS, (THETA(I), I=1,NAC)
   1)      .11100E+01

 CONSTRAINT PARAMETER, BETA =     .71110E+00

 SEARCH DIRECTION (S-VECTOR)
   1)     -.10000E+01  -.17270E-01   .93199E+00   .24047E-01  -.30725E+00

 ONE-DIMENSIONAL SEARCH
 INITIAL SLOPE =  -.7640E+04  PROPOSED ALPHA =    .1358E+00



* * CONSTRAINED ONE-DIMENSIONAL SEARCH INFORMATION * * *

 PROPOSED DESIGN
 ALPHA =   .13594E+00
 X-VECTOR
.3611E+02   .1967E+00   .6783E+02   .4962E-02   .9607E+01

 OBJ =  -.15027E+05

 CONSTRAINT VALUES
-.6106E+00  -.4894E+00  -.5144E+00  -.3485E+01   .2546E+00  -.1025E+02

 TWO-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =   .13354E+00
 X-VECTOR
.3826E+02   .1967E+00   .6764E+02   .4962E-02   .9695E+01

 OBJ =  -.15008E+05

 CONSTRAINT VALUES
-.6095E+00  -.4905E+00  -.5152E+00  -.3485E+01   .1411E-01  -.1001E+02

 THREE-POINT INTERPOLATION


 PROPOSED DESIGN
 ALPHA =   .13334E+00
 X-VECTOR
.3827E+02   .1967E+00   .6763E+02   .4962E-02   .9695E+01

 OBJ =  -.15006E+05
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 CONSTRAINT VALUES
-.6094E+00  -.4906E+00  -.5153E+00  -.3485E+01   .7485E-02  -.1001E+02

 * * * END OF ONE-DIMENSIONAL SEARCH

 CALCULATED ALPHA =   0.

 OBJ =   -.140857E+05     NO CHANGE ON OBJ

 DECISION VARIABLES (X-VECTOR)
   1)     .44362E+02   .13712E+00   .60287E+02   .49455E-02   .59852E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.56625E+00  -.53375E+00  -.53022E+00  -.34698E+01  -.10003E+02   .26773E-02




FINAL OPTIMIZATION INFORMATION

 OBJ =   -.140857E+05

 DECISION VARIABLES (X-VECTOR)
   1)     .44362E+02   .13712E+00   .60287E+02   .49455E-02   .59852E+01

 CONSTRAINT VALUES (G-VECTOR)
   1)    -.56625E+00  -.53375E+00  -.53022E+00  -.34698E+01  -.10003E+02   .26773E-02

 THERE ARE    1 ACTIVE CONSTRAINTS
 CONSTRAINT NUMBERS ARE
     6

 THERE ARE    0 VIOLATED CONSTRAINTS

 THERE ARE    0 ACTIVE SIDE CONSTRAINTS

 TERMINATION CRITERION
      ITER EQUALS ITMAX

 NUMBER OF ITERATIONS =    5

 OBJECTIVE FUNCTION WAS EVALUATED          41  TIMES

 CONSTRAINT FUNCTIONS WERE EVALUATED       41  TIMES
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*****FLAME RESULTS*****

THE FUEL IS CO
THE OXIDIZER IS N2 O

CHI = 0.0000 Q = 0.0000 F = 5.9652 S = 0.0000 ET.N2 = 1.0000

REACTANTS

	MASS	MOLE
CARBON	0.0000	0.0000
CHON	.1163	.1252
N( )O( )	.1836	.1252
N2	.6995	.7495
CO2	0.0000	0.0000

PRODUCTS

	MASS	MOLE
CO2	.1836	.1252
H2O	0.0000	0.0000
O2	0.0000	0.0000
N2	.8164	.8748

FUEL-AIR RATIO = .1323 EXCESS AIR = 0.0000

FLAME TEMP = 1566.2508 DEG. K
DELNX = 0.000 DEG. K ADDITIONAL N2O ENTHALPY = 0. BTU/MOLE
DELN2 = 0.000 DEG.K ADDITIONAL ENTHALPY = 0. BTU/MOLE FOR 1.00 OF THE TOTAL NITROGEN

*****AVCO GAIN MODEL, NASA/AMES VERSION 2.0*****
GDL OPTIMIZATION SAMPLE
OPTIMUM GDL
N2O OXIDIZER

NOZZLE THROAT HEIGHT (MM) = .19712
NOMINAL RATE FOR PC2H

TSTAG = 1566.25 DEG K PSTAG = 44.3621 ATM AEXIT/A* = 60.29 XMAX = 30.00 ANGLE = 0.00

CO2 FRACTION = .12523 H2O FRACTION = .00495 CO FRACTION = .00000 HE FRACTION = 0.00000 H2 FRACTION = .00000

N2 FRACTION = .86982 J = 0 ITAUSB = 0 IRSTRT = 0 IFLUX = 0 ISUB = 6 IRATE = 0 IH2 = 1

IPLOT = 3 IJ = 0 DELX = 2.0000 FLSUE = .103957 CM ELNOZ = 4.37000 CM SLOPE = 37.883400

CURVE = 0.000000 NMAX = 100000 DXMAX = .5000000 DXMIN = .0001000000 CETEST = 10.00

C = 0.000000 RAD = 0.000000 THETA1 = 0.0000 THETA2 = 0.0000 FROZEN GAMMA = 1.35960475

CM1 = .1314568E+02 CM2 = .6073399E+02 CM3 = .1261436E+03 CM4 = -.7642326E+02 CM5 = -.3515258E+03

THE STANDARD DEVIATION FOR THE CMS IS 0.000000 THE NUMBER OF POINTS TAKEN IS 0

FRICTION FACTOR = 0.00000 PROPESS GAMMA = 1.26161 WEIGHTED GAS CONSTANT OF MIXTURE ERGS/GM-DEG K = .27743E+07

SWITCHOVER AT M = 1.050000 A/A* = 1.002029 X = .00002 CM

B1 = .100E+01 B2 = .500E+00 B3 = .100E+01 B4 = .143E+00 B5 = .100E+01 B6 = .100E+01

B7 = .100E+01 B8 = .10E+01 B10= .100E+01 B11= .100E+01 B17= .100E+01 B18= .100E+01

B19= .100E+01

TRANSITION LIFETIME = .538E+01 SEC

OPTICAL CROSS SECTIONS = .130E-13 CM2 FOR CO2, = .670E-14 CM2 FOR N2, = .360E-14 CM2 FOR H2O, = .370E-14 CM2 FOR HE

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TC1(DEG K)	TC2(DEG K)	TC3(DEG K)	TN(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTC1/DX	DTC2/DX	DTC3/DX	DTN/DX	DTH2O/DX
N	U(CM/SEC)	EC1/R(DEG K)	EC2/R(DEG K)	EC3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LC2N	1/LC2C	1/LC2H	1/LC3N	1/LNH2	1/LC32	1/LC32C	1/L32H	1/LC2HE
1/LNHE	1/LC32HE	HST/R(DEG K)	TCO(DEG K)	ECO/R(DEG K)	DTCO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB C(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLJP(W/CM2)	MAX GAIN	J/LB GMAX	J AT GMAX	PHI(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)
-.10396E+00	.63413E-01	.91483E+01	.44237E+02	.15653E+04	.15653E+04	.15653E+04	.15653E+04	.15653E+04	.15653E+04
.10000E-03	-.13742E+01	.19729E+03	.53910E+01	.54462E+02	0.	0.	0.	0.	0.
0	.49437E+04	.99784E+02	.23404E+03	.55219E+02	.38797E+03	.34056E+01	.83042E+03	0.	.28912E+01
.39771E+00	.27077E+05	.50700E+05	.16969E+06	.25984E+05	.51495E+05	.81720E+04	.94300E+04	.60923E+04	.14101E+08
.17828E+06	.31044E+06	.63172E+04	.15653E+04	.49964E-17	0.	.15653E+04	.11401E-17	0.	
-.83957E-01	.73707E-01	.76776E+01	.44194E+02	.15649E+04	.15650E+04	.15650E+04	.15650E+04	.15650E+04	.15650E+04
.10000E-03	.13561E+01	-.14309E+03	-.61773E+01	-.48367E+02	-.47650E+02	-.47650E+02	-.47742E+02	-.46076E+02	-.46260E+02
200	.57456E+04	.99747E+02	.23396E+03	.55191E+02	.38778E+03	.34044E+01	.83008E+03	-.49337E+02	.24014E+01
.34134E+00	.23263E+05	.43558E+05	.14609E+06	.22325E+05	.44241E+05	.70203E+04	.81037E+04	.52356E+04	.14096E+08
.17818E+06	.31034E+06	.63172E+04	.15650E+04	.49541E-17	-.46323E+02	.15649E+04	.13350E-17	-.46366E+02	
-.63957E-01	.10051E+00	.57937E+01	.44050E+02	.15638E+04	.15638E+04	.15638E+04	.15638E+04	.15639E+04	.15639E+04
.10000E-03	.14472E+01	-.82372E+02	-.89535E+01	-.70540E+02	-.68798E+02	-.68798E+02	-.68977E+02	-.66952E+02	-.65659E+02
400	.78321E+04	.99624E+02	.23769E+03	.55035E+02	.38712E+03	.33999E+01	.82893E+03	-.70793E+02	.18052E+01
.24833E+00	.16981E+05	.31796E+05	.10695E+06	.16301E+05	.32293E+05	.51232E+04	.59202E+04	.38537E+04	.14096E+08
.17784E+06	.30990E+06	.63172E+04	.15639E+04	.49861E-17	-.67087E+02	.15638E+04	.13352E-17	-.70537E+02	
-.40516E-01	.17356E+00	.33970E+01	.43439E+02	.15582E+04	.15592E+04	.15592E+04	.15593E+04	.15596E+04	.15595E+04
.16265E-03	.61737E+01	-.11674E+03	-.64335E+02	-.52679E+03	-.48216E+03	-.48216E+03	-.48641E+03	-.43414E+03	-.40093E+03
600	.13503E+05	.99116E+02	.23257E+03	.54701E+02	.38457E+03	.33831E+01	.82435E+03	-.47466E+03	.10095E+01
.13893E+00	.96411E+04	.18052E+05	.61462E+05	.92646E+04	.19331E+05	.29052E+04	.33730E+04	.22113E+04	.14046E+08
.17636E+06	.30800E+06	.63172E+04	.15596E+04	.49549E-17	-.43749E+03	.15589E+04	.13189E-17	-.52673E+03	
.10000E-04	.10004E+01	.10195E+01	.23261E+02	.13376E+04	.14017E+04	.14017E+04	.14056E+04	.14565E+04	.14615E+04
.10366E-05	.24537E+04	.31944E+01	-.66519E+05	-.10913E+07	-.96355E+04	-.96355E+04	-.91722E+04	-.47623E+04	-.32064E+04
716	.72097E+05	.81937E+02	.24446E+03	.42013E+02	.32426E+03	.30630E+01	.69574E+03	-.68056E+04	.33741E-01
.46414E-02	.67295E+03	.12601E+04	.73153E+04	.73951E+03	.12550E+04	.19261E+03	.27603E+03	.31621E+03	.12122E+08
.11598E+06	.22866E+06	.63174E+04	.14521E+04	.41866E-17	-.50569E+04	.13413E+04	.70061E-16	-.16562E+05	
.21403E-04	.10209E+01	.10198E+01	.22707E+02	.13284E+04	.14016E+04	.14016E+04	.14055E+04	.14565E+04	.14618E+04
.10366E-05	.11440E+04	.41633E+02	-.30742E+05	-.51140E+05	-.10773E+05	-.10773E+05	-.12497E+05	-.45713E+04	-.20395E+04
727	.73323E+05	.81924E+02	.24444E+03	.42003E+02	.32423E+03	.30626E+01	.69565E+03	-.73505E+04	.30796E-01
.42363E-02	.63545E+03	.11849E+04	.76836E+04	.70503E+03	.11835E+04	.18153E+03	.26445E+03	.31024E+03	.12041E+08
.11375E+06	.22565E+06	.63174E+04	.14521E+04	.41682E-17	-.45896E+04	.13322E+04	.67941E-16	-.50766E+06	
A/A* AT SWITCHOVER CHANGED FROM .10198E+01 TO .10020E+01 TO MATCH REQUIRED EXIT ARE.. CORRESPONDING ATMOS A/A* = .85805E+01									
.21403E-04	.10209E+01	.10021E+01	.22707E+02	.13284E+04	.14016E+04	.14016E+04	.14055E+04	.14565E+04	.14618E+04
.10000E-03	.28023E+04	.97872E+02	-.75272E+05	-.12552E+07	-.10773E+05	-.10773E+05	-.12497E+05	-.45713E+04	-.20695E+04
727	.73323E+05	.81924E+02	.24444E+03	.42003E+02	.32423E+03	.30629E+01	.69565E+03	-.73505E+04	.30796E-01
.42363E-02	.63545E+03	.11849E+04	.76836E+04	.70503E+03	.11835E+04	.18153E+03	.26445E+03	.31023E+03	.12041E+08
.11375E+06	.22565E+06	.63174E+04	.14521E+04	.41682E-17	-.45896E+04	.13322E+04	.67941E-16	-.50766E+06	
-.36972E-04	-.36961E-04						.10000E+01	.10003E+01	.62423E-02
.20636E+01	.52239E+01	.51191E+02	.38239E-01	.26096E+03	.71184E+03	.71184E+03	.13073E+04	.13643E+04	.66286E+03
.12267E+00	.13433E+00	.10905E+02	-.96626E-02	-.99545E+01	-.10017E+03	-.10017E+03	-.47543E+01	-.60711E+01	-.71665E+02
882	.16647E+05	.17375E+02	.84306E+02	.34501E+02	.27341E+03	.36748E+00	.40995E+03	-.32442E+02	.43613E-11
.59995E-12	.13130E-01	.24546E-01	.91517E+02	.36356E+01	.25621E-02	.76521E-02	.25445E-01	.24955E+01	.26436E+07
.19321E+03	.25429E+05	.63106E+04	.15446E+04	.44476E-17	.2021 E+02	-.23997+260	.50800E-03	-.58390E+04	
.11529E-03	.10742E-03	.73344E+02	.27469E-02	.45932E+04	17		.94371E+00	.94963E+00	.53516E-04

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TC1(DEG K)	TC2(DEG K)	TC3(DEG K)	TN(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(D/A*)	DP/DX	DT/DX	DTC1/DX	DTC2/DX	DTC3/DX	DTN/DX	DTH2O/DX
N	U(CM/SEC)	EC1/R(DEG K)	EC2/R(DEG K)	EC3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LC2N	1/LC2C	1/LC2H	1/LC3N	1/LNH2	1/LC32N	1/LC32S	1/LC32H	1/LC2HE
1/LNHE	1/LC32HE	HST/R(DEG K)	TCO(DEG K)	ECO/R(DEG K)	DTCO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB C(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLUP(W/CM2)	MAX GAIN	U/LB -GMAX	J A) GM/X	PHI(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)

.41279E+01	.52386E+01	.60284E+02	.32496E-01	.26227E+03	.56005E+03	.56005E+03	.13014E+04	.13551E+04	.55405E+03
.14603E+00	-.65142E-01	.48249E-01	.79861E-03	.64875E+01	-.56175E+02	-.56175E+02	-.17044E+01	-.40214E+01	-.42098E+02
907	.16717E+06	.80626E+01	.52625E+02	.34061E+02	.26823E+03	.14323E+00	.36336E+03	-.16277E+02	.39245E-11
.53985E-12	.11198E-01	.20968E-01	.6847CE+02	.33044E+01	.22209E-02	.64891E-02	.21510E-01	.21053E+01	.26526E+07
.19833E+03	.25462E+05	.63148E+04	.15798E+04	.51025E-17	.15341E+02	-.23997+260	.59600E-09	.42247E+04	
.43764E-03	.40633E-03	.16945E+03	.86203E-02	.10365E+05	15		.93251E+00	.93242E+00	.45255E-04
.61903E+01	.51308E+01	.602 7E+02	.33939E-01	.27212E+03	.46645E+03	.46645E+03	.12377E+04	.13475E+04	.47960E+03
.14856E+00	-.38826E-01	0.	.49960E-03	.3910 E+01	-.36004E+02	-.36004E+02	-.19281E+01	-.34006E+01	-.30640E+02
921	.16699E+06	.39859E+01	.35199E+02	.33792E+02	.26417E+03	.955905E-01	.33724E+03	-.96775E+01	.66044E-11
.90651E-12	.12421E-01	.2325 E-01	.67313E+02	.32347E+01	.27920E-02	.60859E-02	.2222 E-01	.21355E+01	.27255E+07
.24725E+03	.25764E+05	.631 4E+04	.16038E+04	.53246E-17	.13785E+02	-.23997+260	.5 600E-09	.56819E+04	
.61705E-03	.57393E-03	.2134 E+03	.12110E-01	.12602E+05	15		.93263E+00	.93254E+00	.45301E-04
.82811E+01	.50680E+01	.602 7E+02	.34661E-01	.27926E+03	.40637E+03	.40637E+03	.12934E+04	.13403E+04	.42526E+03
.15011E+00	-.23014E-01	0.	.30627E-03	.2395 E+01	-.22374E+02	-.22374E+02	-.21306E+01	-.30396E+01	-.21684E+02
935	.16688E+06	.21525E+01	.25004E+02	.33460E+02	.26062E+03	.51668E-01	.32130E+03	-.53347E+01	.69621E-11
.12328E-11	.13223E-01	.2476 E-01	.66616E+02	.31930E+01	.31532E-02	.71439E-02	.22673E-01	.21590E+01	.27715E+07
.27412E+03	.25983E+05	.631 8E+04	.16369E+04	.55271E-17	.12172E+02	-.23997+260	.59600E-09	.55153E+04	
.71053E-03	.66127E-03	.2304 E+03	.14004E-01	.13761E+05	15		.93271E+00	.93261E+00	.45331E-04
.10720E+02	.50292E+01	.602 7E+02	.35163E-01	.28335E+03	.36950E+03	.36950E+03	.12388E+04	.13347E+04	.38747E+03
.15110E+00	-.14660E-01	0.	.19348E-03	.15611E+01	-.13230E+02	-.13230E+02	-.22377E+01	-.26359E+01	-.14420E+02
949	.16681E+06	.13390E+01	.19332E+02	.32144E+02	.25735E+03	.30469E-01	.31120E+03	-.38613E+01	.10826E-10
.14892E-11	.13755E-01	.2575 E-01	.66160E+02	.31663E+01	.34699E-02	.73139E-02	.22956E-01	.21709E+01	.2800 E+07
.29513E+03	.26135E+05	.631 4E+04	.16610E+04	.57030E-17	.10533E+02	-.23997+260	.59600E-09	.47475E+04	
.75268E-03	.70066E-03	.2361 E+03	.14499E-01	.14080E+05	15		.93275E+00	.93266E+00	.45350E-04
.12510E+02	.50033E+01	.602 7E+02	.35536E-01	.28612E+03	.34613E+03	.34613E+03	.12 9 E+04	.132 3E+04	.36330E+03
.15178E+00	-.10235E-01	0.	.14141E-03	.11060E+01	-.73931E+01	-.73931E+01	-.22837E+01	-.27304E+01	-.86424E+01
963	.16677E+06	.9717 2E+00	.18208E+02	.32704E+02	.25425E+03	.20526E-01	.30433E+03	-.27353E+01	.12284E-10
.16899E-11	.14126E-01	.2645 E-01	.65366E+02	.31493E+01	.36683E-02	.74321E-02	.23150E-01	.2171 E+01	.28209E+07
.31006E+03	.26244E+05	.631 8E+04	.16 20E+04	.58674E-17	.92054E+01	-.23997+260	.5 600E-09	.40486E+04	
.76739E-03	.71444E-03	.2374 E+03	.15244E-01	.14126E+05	15		.93278E+00	.93269E+00	.45363E-04
.14638E+02	.49642E+01	.602 7E+02	.35 02E-01	.2861 E+03	.33647E+03	.33647E+03	.12791E+04	.13230E+04	.34955E+03
.15228E+00	-.78942E-02	0.	.11024E-03	.86186E+00	-.38797E+01	-.38797E+01	-.23223E+01	-.26695E+01	-.45337E+01
977	.16673E+06	.8021 E+00	.14713E+02	.32436E+02	.25125E+03	.16015E-01	.2 922 E+03	-.21312E+01	.13462E-10
.18546E-11	.14408E-01	.2697 E-01	.6666 E+02	.31363E+01	.38216E-02	.75216E-02	.23295E-01	.21645E+01	.2935 E+07
.32153E+03	.26326E+05	.631 5E+04	.17001E+04	.60062E-17	.78907E+01	-.23997+260	.5 600E-09	.36126E+04	
.76809E-03	.71514E-03	.2367 E+03	.15302E-01	.14056E+05	15		.93281E+00	.93272E+00	.45373E-04
.16773E+02	.49633E+01	.602 7E+02	.36016E-01	.2896 E+03	.33053E+03	.33053E+03	.12741E+04	.13174E+04	.34283E+03
.15269E+00	-.66409E-02	0.	.93567E-04	.73123E+00	-.13814E+01	-.13814E+01	-.23363E+01	-.26356E+01	-.20363E+01
991	.16670E+06	.72375E+00	.13975E+02	.3201 E+02	.24629E+03	.14063E-01	.2 505E+03	-.1 062E+01	.14536E-10
.19996E-11	.14641E-01	.2741 E-01	.6549 E+02	.31257E+01	.39503E-02	.75955E-02	.23413E-01	.21 90E+01	.28431E+07
.33111E+03	.26399E+05	.631 5E+04	.17157E+04	.61254E-17	.66736E+01	-.23997+260	.5 600E-09	.34162E+04	
.76174E-03	.70925E-03	.2346 E+03	.15214E-01	.13934E+05	15		.93293E+00	.93274E+00	.45331E-04

X(CM)	M	A/A*	P(ATMOS)	T(DEG K)	TC1(DEG K)	TC2(DEG K)	TC3(DEG K)	TN(DEG K)	TH2O(DEG K)
DX	DM/DX	D/DX(A/A*)	DP/DX	DT/DX	DTC1/DX	DTC2/DX	DTC3/DX	DTN/DX	DTH2O/DX
N	U(CM/SEC)	EC1/R(DEG K)	EC2/R(DEG K)	EC3/R(DEG K)	EN/R(DEG K)	EH2O/R(DEG K)	EVTOT/R	D(EVIB/R)/DX	1/LNN(1/CM)
1/LNC	1/LC2N	1/LC2C	1/LC2H	1/LC3N	1/LNH2	1/LC32N	1/LC32C	1/LC32H	1/LC2HE
1/LNHE	1/LC32HE	HST/R(DEG K)	TCO(DEG K)	ECO/R(DEG K)	DTCO/DX	TH2(DEG K)	EH2/R(DEG K)	DTH2/DX	NU SUB C(1/SEC)
GAINJP(1/CM)	GAINJR(1/CM)	FLJP(W/CM2)	MAX GAIN	J/LB _GMAX	J AT GMAX	PHI(W/CM2)	DOP FAC P	DOP FAC R	DENS(G/CM3)
.18913E+02	.49555E+01	.60267E+02	.36207E-01	.29134E+03	.32760E+03	.32760E+03	.12631E+04	.13117E+04	.34006E+03
.15305E+00	-.59576E-02	0.	.84596E-04	.66045E+00	-.78461E+00	-.76461E+00	-.23425E+01	-.26150E+01	-.71132E+00
1005	.16668E+06	.63939E+00	.13583E+02	.31722E+02	.24536E+03	.13320E-01	.29138E+03	-.16342E+01	.15523E-10
.21353E-11	.14849E-01	.27803E-01	.65337E+02	.31165E+01	.40661E-02	.76612E-02	.23518E-01	.21930E+01	.28539E+07
.33971E+03	.26461E+05	.63183E+04	.17268E+04	.62262E-17	.55619E+01	-.23997+260	.59700E-09	.33966E+04	
.75188E-03	.70008E-03	.23239E+03	.15051E-01	.13717E+05	15		.33245E+00	.33275E+00	.45381E-04
.21058E+02	.49431E+01	.60267E+02	.36363E-01	.29273E+03	.32660E+03	.32660E+03	.12641E+04	.13062E+04	.33930E+03
.15339E+00	-.55713E-02	0.	.79684E-04	.62237E+00	-.20575E+00	-.20575E+00	-.23446E+01	-.26015E+01	-.69736E-01
1019	.16665E+06	.67711E+00	.13455E+02	.31363E+02	.24245E+03	.13122E-01	.28799E+03	-.15387E+01	.16490E-10
.22683E-11	.15043E-01	.28167E-01	.65154E+02	.31079E+01	.41757E-02	.77227E-02	.23615E-01	.21966E+01	.28690E+07
.34781E+03	.26520E+05	.63189E+04	.17396E+04	.63096E-17	.45276E+01	-.23997+260	.59800E-09	.34864E+04	
.74031E-03	.68932E-03	.22971E+03	.14852E-01	.13627E+05	15		.33286E+00	.33277E+00	.45394E-04
.23207E+02	.49314E+01	.60267E+02	.36551E-01	.29404E+03	.32672E+03	.32672E+03	.12590E+04	.13006E+04	.33951E+03
.15371E+00	-.53395E-02	0.	.76892E-04	.60041E+00	.10026E+00	.10026E+00	-.23446E+01	-.25916E+01	.22360E+00
1033	.16663E+06	.67616E+00	.13445E+02	.31004E+02	.23961E+03	.13176E-01	.28475E+03	-.14643E+01	.17464E-10
.24024E-11	.15231E-01	.28519E-01	.65056E+02	.30950E+01	.42826E-02	.77819E-02	.23705E-01	.22000E+01	.26766E+07
.35568E+03	.26577E+05	.63186E+04	.17463E+04	.63772E-17	.35703E+01	-.23997+260	.59600E-09	.36537E+04	
.72795E-03	.67783E-03	.22643E+03	.14634E-01	.13463E+05	15		.33281E+00	.33279E+00	.45400E-04
.25361E+02	.49201E+01	.60267E+02	.36715E-01	.29532E+03	.32712E+03	.32712E+03	.12540E+04	.12950E+04	.34015E+03
.15402E+00	-.51881E-02	0.	.75209E-04	.58711E+00	.25908E+00	.25908E+00	-.23432E+01	-.25836E+01	.35201E+00
1047	.16661E+06	.68112E+00	.13497E+02	.30647E+02	.23675E+03	.13345E-01	.28154E+03	-.14514E+01	.16463E-10
.25399E-11	.15416E-01	.28865E-01	.64927E+02	.30919E+01	.43387E-02	.78402E-02	.23739E-01	.22033E+01	.25680E+07
.36348E+03	.26634E+05	.63189E+04	.17550E+04	.64295E-17	.26533E+01	-.23997+260	.59300E-09	.38677E+04	
.71528E-03	.66604E-03	.22410E+03	.14409E-01	.13295E+05	15		.33269E+00	.33260E+00	.45406E-04
.27365E+02	.49096E+01	.60267E+02	.36864E-01	.29640E+03	.32773E+03	.32773E+03	.12493E+04	.12898E+04	.34092E+03
.15431E+00	-.50556E-02	0.	.74169E-04	.57594E+00	.33629E+00	.33629E+00	-.23414E+01	-.25770E+01	.40304E+00
1060	.16659E+06	.68356E+00	.13574E+02	.30316E+02	.23411E+03	.13549E-01	.27870E+03	-.14309E+01	.19420E-10
.26715E-11	.15586E-01	.29155E-01	.64806E+02	.30647E+01	.44575E-02	.78935E-02	.23683E-01	.22063E+01	.28366E+07
.37071E+03	.26687E+05	.63188E+04	.17596E+04	.64653E-17	.19137E+01	-.23997+260	.59100E-09	.40473E+04	
.70345E-03	.65503E-03	.22146E+03	.14196E-01	.13139E+05	15		.33291E+00	.33261E+00	.45412E-04
.29373E+02	.48937E+01	.60267E+02	.37012E-01	.29764E+03	.32845E+03	.32645E+03	.12445E+04	.12847E+04	.34175E+03
.15459E+00	-.50023E-02	0.	.73397E-04	.57264E+00	.37709E+00	.37709E+00	-.23391E+01	-.25707E+01	.42367E+00
1073	.16657E+06	.69749E+00	.13667E+02	.29986E+02	.23146E+03	.13773E-01	.27584E+03	-.14155E+01	.20412E-10
.28075E-11	.15757E-01	.29564E-01	.64683E+02	.30776E+01	.45863E-02	.79474E-02	.23965E-01	.22092E+01	.29052E+07
.37796E+03	.26739E+05	.63184E+04	.17627E+04	.64857E-17	.12075E+01	-.23997+260	.59000E-09	.43500E+04	
.69166E-03	.64406E-03	.21811E+03	.13984E-01	.12932E+05	15		.33232E+00	.33233E+00	.45417E-04
.30146E+02	.48858E+01	.60267E+02	.37061E-01	.29801E+03	.32874E+03	.32874E+03	.12423E+04	.12827E+04	.34206E+03
.15470E+00	-.49742E-02	0.	.73144E-04	.57066E+00	.36647E+00	.36647E+00	-.23381E+01	-.25683E+01	.42753E+00
1078	.16656E+06	.70113E+00	.13705E+02	.29860E+02	.23047E+03	.13462E-01	.27475E+03	-.14106E+01	.20682E-10
.28515E-11	.15822E-01	.29627E-01	.64643E+02	.30741E+01	.46254E-02	.79679E-02	.23497E-01	.22105E+01	.29054E+07
.38077E+03	.26760E+05	.63183E+04	.17635E+04	.64962E-17	.47575E+00	-.23997+260	.59000E-09	.44923E+04	
.68715E-03	.63986E-03	.21773E+03	.13703E-01	.12903E+05	17		.33233E+00	.33272E+00	.45419E-04

***** OPTIMUM GDL
***** N2O OXIDIZER

GDL OPTIMIZATION SAMPLE

THE MAXIMUM GAIN IS .15302E+01 PCT/CM THIS OCCURS AT X = 14.63736 CM
THE 1/2 OF THE MAX GAIN IS .76511E+00 PCT/CM THIS OCCURS AT X = 3.78725 CM

THERE IS NO VALUE OF GAIN SUITABLE FOR THE REQUIRED CONDITION

THE NUMBER CHARACTERIZING THE TRAILING PORTION OF THE CURVE IS .9552042
THE NUMBER CHARACTERIZING THE CURVATURE OF THE TRAILING PORTION OF THE CURVE IS .5102159
THE NUMBER AVERAGE SLOPE IS -.00902

THE AVERAGE SPECIFIC POWER OVER A 10.000 CM DISTANCE IS 14005.6771 J/LB.
IT WAS AVERAGED BETWEEN 8.201 CM AND 18.201 CM.

WEIGHT/VOLUME RESULTS

TOTAL PRESSURE (PSI)	552.12	STAGNATION TEMPERATURE (DEGREES KELVIN)	1566.25
TOTAL POWER (WATTS)	500000.00	SPECIFIC POWER (JOULES/LBM)(EFF = 1.00)	14035.68
NUMBER OF SHOTS	15	SHOT LENGTH (SECONDS/FIRING)	2.00
TOTAL FLOW TIME (SECONDS)	40.00	MASS FLOW RATE (LBM/SECOND)	35.78
LASER AND MIRROR HEIGHT (INCHES)	5.00	LASER WIDTH (INCHES)	73.66
CAVITY ASPECT RATIO	14.73	NOZZLE BOUNDARY LAYER FACTOR	.5554266-05
DIFFUSER LENGTH (INCHES)	7.23	REQUIRED DIFFUSER ENTRANCE PRESSURE (PSI)	552.10
DIFFUSER EXIT MACH NUMBER	.20	DIFFUSER EXIT PRESSURE (PSI)	14.78

SYSTEM AND SUBSYSTEM WEIGHTS AND VOLUMES

	WEIGHT (LBM)	VOLUME (FT**3)
*COMBUSTOR	79.34	3.675
*CAVITY, NOZZLE, MANIFOLD	361.49	5.871
SIDEWALL	116.13	
NOZZLE	171.73	
ENDWALL	60.00	
MANIFOLD	13.63	
*STRUCTURE	107.66	
*MOUNTS	43.11	
*DIFFUSER (ETA = .60)	558.21	1.541
VANES (55)	149.10	
SIDEWALLS	31.15	
ENDWALLS	356.33	
MOUNTS	12.63	
*OPTICAL BENCH	39.51	10.140
*ADVANCED OPTICAL BENCH	500.00	10.000
*FUEL SUPPLY SYSTEM	1643.04	65.532
FUEL	1478.40	23.569
TANK	44.35	
PUMP	69.25	2.856
VALVE	71.04	23.578
*MISCELLANEOUS	351.00	16.000
TOTAL	3215.49	122.459
TOTAL USING ADVANCED BENCH	3675.91	122.31s

Figure 3.- Concluded

REFERENCES

1. Otten, L. J., III; Saunders, R. C., III; and Morris, S. J.: System Optimization of Gasdynamic Lasers. NASA TM X-73,192, 1976.

2. Saunders, R. C., III; and Otten, L. J., III: Proceedings of the Symposium on Gasdynamic and Chemical Lasers, Cologne, Oct. 1976.

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15. Supplementary Notes

16. Abstract

This report contains the user's manual for a computer program that performs system optimization of gasdynamic lasers. Detailed input/output formats are CDC 7600/6600 computers using a dialect of FORTRAN. The manual is intended to be used in conjunction with NASA TM-73,192, "System Optimization of Gasdynamic Lasers," which contains the program structure. Sample input/output data are provided to verify correct program operation along with a program listing.

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